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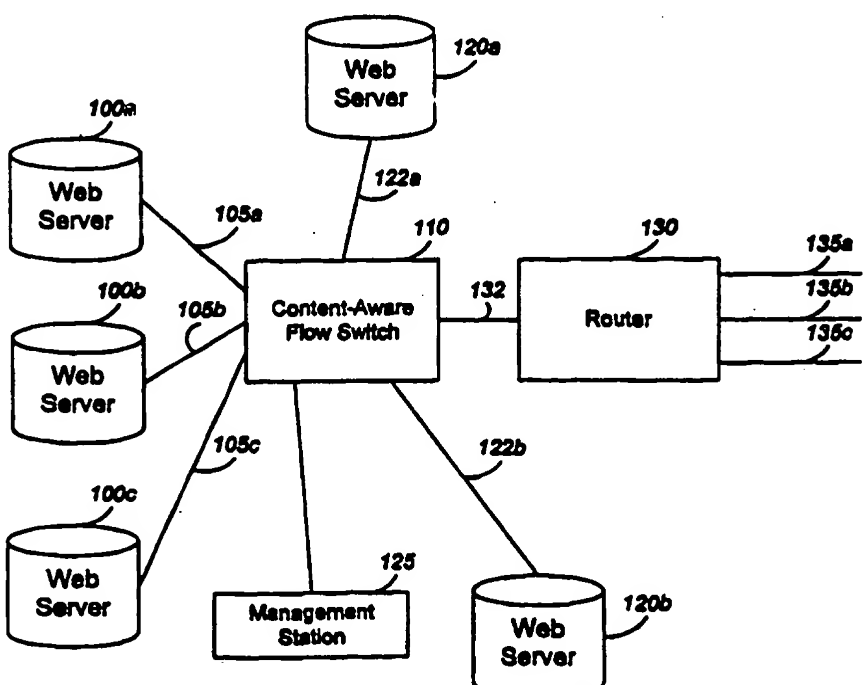


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(57) Abstract

A content-aware flow switch (110) intercepts a client content request in an IP network (100), and transparently directs the content request to a best-fit server. The best-fit server is chosen based on the type of content requested, the quality of service requirements implied by the content request, the degree of load on available servers (100a–c), network congestion information, and the proximity of the client to available servers. The flow switch (110) detects client-server flows based on the arrival of TCP SYNs and/or HTTP GETs from the client.

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# CONTENT-AWARE FLOW SWITCHING

## References to Related Applications

This application claims priority from a provisional application Ser. No. 60/054,687, filed August 1, 1997, which is hereby incorporated by reference.

## Background of the Invention

The present invention relates to content-based flow switching in Internet Protocol (IP) networks.

IP networks route packets based on network address information that is embedded in the headers of packets. In the most general sense, the architecture of a typical data switch consists of four primary components: (1) a number of physical network ports (both ingress ports and egress ports), (2) a data plane, (3) a control plane, and (4) a management plane. The data plane, sometimes referred to as the "fastpath," is responsible for moving packets from ingress ports of the data switch to egress ports of the data switch based on addressing information contained in the packet headers and information from the data switch's forwarding table. The forwarding table contains a mapping between all the network addresses the data switch has previously seen and the physical port on which packets destined for that address should be sent. Packets that have not previously been mapped to a physical port are directed to the control plane. The control plane determines the physical port to which the packet should be forwarded. The control plane is also responsible for updating the forwarding table so that future packets to the same destination may be forwarded directly by the data plane. The data plane functionality is commonly performed in hardware. The management plane performs administrative functions such as providing a user interface (UI) and managing Simple Network Management Protocol (SNMP) engines.

Packets conforming to the TCP/IP Internet layering model have 5 layers of headers containing network address information, arranged in increasing order of abstraction. A data switch is categorized as a layer N switch if it makes switching decisions based on address information in the $N^{th}$ layer of a packet header. For example, both Local Area Network (LAN, layer 2) switching and IP (layer 3) switching switch packets based solely on address information contained in transmitted packet headers. In the case of LAN switching, the destination MAC address is used for switching, and in the case of IP switching, the destination IP address is used for switching.

Applications that communicate over the Internet typically communicate with each other over a transport layer (layer 4) Transmission Control Protocol (TCP) or User Datagram Protocol (UDP) connection. Such applications need not be aware of the switching that occurs at lower levels (levels 1-3) to support the layer 4 connection. For example, an HyperText Transfer Protocol (HTTP) client (also known as a web browser) exchanges HTTP (layer 5) control messages and data (payload) with a target web server over a TCP (layer 4) connection.

"Content" can be loosely defined as any information that a client application is interested in receiving. In an IP network, this information is typically delivered by an application-layer server application using TCP or UDP as its transport layer. The content itself may be, for example, a simple ASCII text file, a binary file, an HTML page, a Java applet, or real-time audio or video.

A "flow" is a series of frames exchanged between two connection endpoints defined by a layer 3 network address and a layer 4 port number pair for each end of the connection. Typically, a flow is initiated by a

request at one of the two connection endpoints for content which is accessible through the other connection endpoint. The flow that is created in response to the request consists of (1) packets containing the requested content, and (2) control messages exchanged between the two endpoints.

Flow classification techniques are used to associate priority codes with flows based on their Quality of Service (QoS) requirements. Such techniques prioritize network requests by treating flows with different QoS classes differently when the flows compete for limited network resources. Flows in the same QoS class are assigned the same priority code. A flow classification technique may, for example, classify flows based on IP addresses and other inner protocol header fields. For example, a QoS class with a particular priority may consist of all flows that are destined for destination IP address 142.192.7.7 and TCP port number 80 and TOS of 1 (Type of Service field in the IP header). This technique can be used to improve QoS by giving higher priority flows better treatment.

Internet Service Providers (ISPs) and other Internet Content Providers commonly maintain web sites for their customers. This service is called web hosting. Each web site is associated with a web host. A web host may be a physical web server. A web host may also be a logical entity, referred to as a virtual web host (VWH). A virtual web host associated with a large web site may span multiple physical web servers. Conversely, several virtual web hosts associated with small web sites may share a single physical web server. In either case, each virtual web host provides the functionality of a single physical web server in a way that is transparent to the client. The web sites hosted on a virtual web host share server resources, such as CPU cycles and memory, but are

provided with all of the services of a dedicated web server. A virtual web host has one or more public virtual IP address that clients use to access content on the virtual web host. A web host is uniquely identified by its public IP address. When a content request is made to the virtual web host's virtual IP address, the virtual IP address is mapped to a private IP address, which points either to a physical server or to a software application identified by both a private IP address and a layer 4 port number that is allocated to the application.

## Summary of the Invention

In one aspect, the invention features content-aware flow switching in an IP network. Specifically, when a client in an IP network makes a content request, the request is intercepted by a content-aware flow switch, which seamlessly forwards the content request to a server that is well-suited to serve the content request. The server is chosen by the flow switch based on the type of content requested, the QoS requirements implied by the content request, the degree of load on available servers, network congestion information, and the proximity of the client to available servers. The entire process of server selection is transparent to the client.

In another aspect, the invention features implicit deduction of the QoS requirements of a flow based on the content of the flow request. After a flow is detected, a QoS category is associated with the flow, and buffer and bandwidth resources consistent with the QoS category of the flow are allocated. Implicit deduction of the QoS requirements of incoming flow requests allows network applications to significantly improve their Quality of Service (QoS) behavior by (1) preventing over-allocation of system resources, and (2) enforcing fair competition among flows for limited system resources based on their

QoS classes by using a strict priority and weighted fair queuing algorithm.

In another aspect, the invention features flow pipes, which are logical pipes through which all flows between virtual web hosts and clients travel. A single content-aware flow switch can support multiple flow pipes. A configurable percentage of the bandwidth of a content-aware flow switch is reserved for each flow pipe.

In another aspect, the invention features a method for selecting a best-fit server, from among a plurality of servers, to service a client request for content in an IP network. A location of the client is identified. A location of each of the plurality of servers is identified. Servers that are in the same location as the client are identified. A server from among the plurality of servers is selected as the best-fit server, using a method which assigns a proximity preference to the identified servers. The location of the client may be a continent in which the client resides. The location of each of the plurality of servers may be a continent in which the server resides. Servers that are in the same location as the client may be identified by identifying administrative authorities associated with the client based on its IP address, identifying, for each of the plurality of servers, administrative authorities associated with the server, and identifying servers associated with an administrative authority that is associated with the client. The administrative authorities may be Internet Service Providers.

One advantage of the invention is that content-aware flow switches can be interconnected and overlaid on top of an IP network to provide content-aware flow switching regardless of the underlying technology used by the IP network. In this way, the invention provides

content-aware flow switching without requiring modifications to the core of existing IP networks.

Another advantage of the invention is that by using content-aware flow switching, a server farm may gracefully absorb a content request spike beyond the capacity of the farm by directing content requests to other servers. This allows mirroring of critical content in distributed data centers, with overflow content delivery capacity and backup in the case of a partial communications failure. Content-aware flow switches also allow individual web servers to be transparently removed for service.

Another advantage of the invention is that it performs admission control on a per flow basis, based on the level of local network congestion, the system resources available on the content-aware flow switch, and the resources available on the web servers front-ended by the flow switch. This allows resources to be allocated in accordance with individual flow QoS requirements.

One advantage of flow pipes is that the virtual web host associated with a flow pipe is guaranteed a certain percentage of the total bandwidth available to the flow switch, regardless of the other activity in the flow switch. Another advantage of flow pipes is that the quality of service provided to the flows in a flow pipe is tailored to the QoS requirements implied by the content of the individual flows.

Another advantage of the invention is that, when performing server selection, a server in the same continent as the client is preferred over servers in another continent. Trans-continental network links introduce delay and are frequently congested. The server selection process tends to avoid such trans-continental links and the bottlenecks they introduce.

Another advantage of the invention is that, when performing server selection, a server that shares a "closest" backbone ISP with the client is preferred. Backbone ISPs connect with one another at Network Access Points (NAP). NAPs frequently experience congestion. By selecting a path between a client and a server that does not include a NAP, bottlenecks are avoided.

Other features and advantages of the invention will become apparent from the following description and from the claims.

Brief Description of the Drawings

FIG. 1a is a block diagram of an IP network.

FIG. 1b is a block diagram of a segment of a network employing a content-aware flow switch.

FIG. 1c is a block diagram of traffic flow through a content-aware flow switch.

FIG. 2 is a block diagram illustrating operations performed by and communications among components of a content-aware flow switch during flow setup.

FIG. 3 is a flow chart of a method for servicing a content request using a content-aware flow switch.

FIG. 4 is a flow chart of a method for parsing a flow setup request.

FIGS. 5 and 6 are flow charts of methods for sorting a list of candidate servers.

FIG. 7 is a flow chart of a method for evaluating requested content.

FIG. 8 is a flow chart of a method for sorting a list of candidate servers.

FIG. 9 is a flow chart of a method for filting servers from a list of candidate servers.

FIG. 10 is a flow chart of a method for evaluating a server in a list of candidate servers.

FIG. 11 is a flow chart of a method for ordering a server in a list of candidate servers.

FIGS. 12-16 are flows charts of methods for assigning a status to a server for purposes of ordering the server in a list of candidate servers.

FIG. 17 is a flow chart of a method for assigning a flow to a local server.

FIG. 18 is a flow chart of a method for attempting to satisfy a request for a flow.

FIG. 19 is a flow chart of a method for constructing a QoS tag.

FIG. 20 is a flow chart of a method for locating QoS tags which are similar to a given QoS tag.

FIGS. 21a-b are block diagrams of flow pipe traffic through a content-aware flow switch.

FIG. 22 is a flow chart of a method for ordering servers in a list of candidate servers based on proximity.

FIG. 23 is a block diagram of a computer and computer elements suitable for implementing elements of the invention.

## Detailed Description

Referring to FIG. 1a, in a conventional IP network 100, such as the Internet, servers are connected to routers at the edges of the network 100. Each router is connected to one or more other routers. Each stream of information transmitted from one end station to another is broken into packets containing, among other things, a destination address indicating the end station to which the packet should be delivered. A packet is transmitted from one end station to another via a sequence of routers. For example, a packet may originate at server S1, traverse routers R1, R2, R3, and R4, and then be delivered to server S2.

In FIG. 1a, a network node is either a router or an end station. Each router has access to information about each of the nodes to which the router is connected.

When a router receives a packet, the router examines the packet's destination address, and forwards the packet to a node that the router calculates to be most likely to bring the packet closer to its destination address. The process of choosing an intermediary destination for a packet and forwarding the packet to the intermediary destination is called routing.

For example, referring to FIG. 1a, server S1 transmits a packet, whose destination address is server S2, to router R1. Router R1 is only connected to server S1 and to router R2. Router R1 therefore forwards the packet to router R2. When the packet reaches router R2, router R2 must choose to forward the packet to one of routers R1, R5, R3, and R6 based on the packet's destination IP address. The packet is passed from router to router until it reaches its destination of server S2.

Referring to FIG. 1b, web servers 100a-c and 120a-b are connected to a content-aware flow switch 110. The web servers 100a-c are connected to the flow switch 110 over LAN links 105a-c. The web servers 120a-b are connected to the flow switch 110 over WAN links 122a-b. The flow switch 110 may be configured and its health monitored using a network management station 125. The role of the management station 125 is to control and manage one or more communications devices from an external device such as a workstation running network management applications. The network management station 125 communicates with network devices via a network management protocol such as the Simple Network Management Protocol (SNMP). The flow switch 110 may connect to the network 100 (FIG. 1a) through a router 130. The flow switch 110 is connected to the router 130 by a LAN or WAN link 132. Alternatively, the flow switch 110 may connect to the network 100 directly via one or more WAN links (not shown). The router 130 connects to an Internet

Service Provider (ISP) (not shown) by multiple WAN links 135a-c.

Referring to FIG. 1c, a content-aware flow switch "front-ends" (i.e., intercepts all packets received from and transmitted by) a set of local web servers 100a-c, constituting a web server farm 150. Although connections to the web servers 100a-c are typically initiated by clients on the client side, most of the traffic between a client and the server farm 150 is from the servers 100a-c to the client (the response traffic). It is this response traffic that needs to be most carefully controlled by the flow switch 110.

The flow switch 110 has a number of physical ingress ports 170a-c and physical egress ports 165a-c. Each of the physical ingress ports 170a-c may act as one or more logical ingress ports, and each of the physical egress ports 165a-c may act as one or more logical egress ports in the procedures described below. Each of the web servers 100a-c is network accessible to the content-aware flow switch 110 via one or more of the physical egress ports 165a-c. Associated with each flow controlled by the flow switch 110 is a logical ingress port and a logical egress port.

The flow switch 110 is connected to an internet through uplinks 155a-c. When a client content request is accepted by the flow switch 110, the flow switch 110 establishes a full-duplex logical connection between the client and one of the web servers 100a-c through the flow switch 110. Individual flows are aggregated into pipes, as described in more detail below. Request traffic flows from the client toward the server and response traffic flows from the server to the client. A component of the flow switch 110, referred to as the Flow Admission Control (FAC), polices if and how flows are admitted to the flow switch 110, as described in more detail below.

The content-aware flow switch 110 differs from typical layer 2 and layer 3 switches in several respects. First, the data plane of layer 2 and layer 3 switches forwards packets based on the destination addresses in the packet headers (the MAC address and header information in the case of a layer 2 switch and the destination IP address in the case of a layer 3 switch). The content-aware flow switch 110 switches packets based on a combination of source and destination IP addresses, transport layer protocol, and transport layer source and destination port numbers. Furthermore, the functions performed in the control plane of typical layer 2 and layer 3 switches are based on examination of the layer 2 and layer 3 headers, respectively, and on well-known bridging and routing protocols. The control plane of the content-aware flow switch 110 also performs these functions, but additionally derives the forwarding path from information contained in the packet headers up to and including layer 5. In addition, content-induced QoS and bandwidth requirements, server loading and network path optimization are also considered by the content-aware flow switch 110 when selecting the most optimal path for a packet, as described in more detail below.

FIG. 2 is a block diagram illustrating, at a high level, operations performed by and communications among components of the content-aware flow switch 110 during flow setup. An arrow between two components in FIG. 2 indicates that communication occurs in the direction of the arrow between the two components connected by the arrow.

Referring to FIG. 2, the content-aware flow switch 110 includes: a Web Flow Redirector (WFR), an Intelligent Content Probe (ICP), a Content Server Database (CSD), a Client Capability Database (CCD), a Flow Admission

Control (FAC), an Internet Probe Protocol (IPP), and an Internet Proximity Assist (IPA).

The CSD maintains several databases containing information about content flow characteristics, content locality, and the location of and the load on servers, such as servers 100a-c and 120a-b. One database maintained by the CSD contains content rules, which are defined by the system administrator and which indicate how the flow switch 110 should handle requests for content. Another database maintained by the CSD contains content records which are derived from the content rules. Content records contain information related to particular content, such as its associated IP address, URL, protocol, layer 4 port number, QoS indicators, and the load balance algorithm to use when accessing the content. A content record for particular content also points to server records identifying servers containing the particular content. Another database maintained by the CSD contains server records, each of which contains information about a particular server. The server record for a server contains, for example, the server's IP address, protocol, a port of the server through which the server can be accessed by the flow switch 110, an indication of whether the server is local or remote with respect to the flow switch 110, and load metrics indicating the load on the server.

Information in the CSD is periodically updated from various sources, as described in more detail below. The WFR, CSD, and FAC are responsible for selecting a server to service a content request based on a variety of criteria. The FAC uses server-specific and content-specific information together with client information and QoS requirements to determine whether to admit a flow to the flow switch 110. The ICP is a lightweight HTTP client whose job is to populate the CSD with server and

content information by probing servers for specific content that is not found in the CSD during a flow setup. The ICP probes servers for several reasons, including: (1) to locate specific content that is not already stored in the CSD, (2) to determine the characteristics of known content such as its size, (3) to determine relationships between different pieces of content, and (4) to monitor the health of the servers. ICPs on various flow switches communicate with each other using the IPP, which periodically sends local server load and content information to neighboring content-aware flow switches. The CCD contains information related to the known capabilities of clients and is populated by sampling specific flows in progress. The IPA periodically updates the CSD on the internet proximity of servers and clients.

A flow setup request may take the form of a TCP SYN from a client being forwarded to the WFR (202). The WFR passes the flow setup request to the CSD (204). The CSD determines which servers, if any, are available to service the flow request and generates a list of such candidate servers (206). This list of candidate servers is ordered based on configurable CSD preferences. The individual items within this list contain all the information the FAC will ultimately need to make flow admission decisions.

If more than one server exists in the server farm 150 and content is not fully replicated among the servers in the server farm, then it may not be possible for the CSD to identify any candidate servers based upon the receipt of the TCP SYN alone. In this case, the CSD returns a NULL candidate server list to the WFR with a status indicator requesting that the TCP connection is to be spoofed and that the subsequent HTTP GET is to be forwarded to the CSD (212).

If the CSD contains no content records for servers that can satisfy the received TCP SYN or HTTP GET, a NULL list is returned to the WFR with a status indicator indicating that the flow request should be rejected (212). If the CSD finds a content record that satisfies the HTTP GET but does not find a record for the specific piece of content requested, a new content record is created containing default values for the specific piece of content requested. The new record is then returned to the WFR (212). In either of these two cases (i.e., the CSD finds no matching records, or the CSD finds a matching record that does not exactly match the requested content), the CSD asks the ICP to probe the local servers (using http "HEAD" operations) to determine where the content is located and to deduce the content's QoS attributes (208).

The CSD then asks the CCD for information related to the client making the request (211). The CCD returns any such information in the CCD to the CSD (210). The CSD returns an ordered list of candidate servers and any client information obtained from the CCD to the WFR (212).

Depending on the response returned from the CSD, the WFR will either: (1) reject, TCP spoof, or redirect the flow as appropriate (214), or (2) forward the flow request, the list of candidate servers, and any client information to the FAC for selection and local setup (216). The FAC evaluates the list of servers contained in the content record, in the order specified by the CSD, and looks for a server that can accept the flow (218). The FAC's primary consideration in selecting a server from the list of candidate servers is that sufficient port and switch resources be available on the content-aware flow switch to support the flow. An accepted flow is assigned either to a VC-pipe or to a flow pipe, as

appropriate. (VC-pipes and flow pipes are described in more detail below.) The FAC also adjusts flow weights as necessary to maintain flow pipe bandwidth.

The FAC informs the WFR of which local server, if any, was chosen to accept the flow, and provides information to the WFR indicating to which specific VC-pipe or flow pipe the flow was assigned (220). The WFR sets up the required network address translations for locally accepted flows so that future packets within the flow can be modified appropriately (222). If the chosen server is "remote" (not in the local server farm) (220), an HTTP redirect is generated (222) that causes the client to go to the chosen remote site for service.

In addition to the steps described above, which occur as part of the flow setup process, the components shown in FIG. 2 perform several other tasks, including the following. Periodically, the ICP probes the servers 100a-c front-ended by the content-aware flow switch 110 for information regarding server status and content. This activity may be undertaken proactively (such as polling for general server health) or at the request of the CSD. The ICP updates the CSD with the results of this search so that future requests for the same content will receive better service (224).

The IPP periodically sends local server load and content information to neighboring content-aware flow switches. Data arriving from these peers is evaluated and appropriate updates are sent to the CSD (226). The IPA periodically updates the CSD with internet proximity information (228).

The operation of the components shown in FIG. 2 is now described in more detail.

Referring to FIG. 3, the WFR services a client content request as follows. When a client sends a content request to a server in the form of a TCP SYN or

HTTP GET, the content request is intercepted by the content-aware flow switch 110, which interprets the request as a request to initiate a flow between the client and an appropriate server (step 402). The CSD is queried for a list of available servers to serve the content request (step 404). The CSD returns a list of candidate servers and the status indicator ACCEPT if the preferred server is known to be in the local server farm. If the CSD returns a status indicator ACCEPT (decision step 406), then the content request may be served at one of the local servers 100a-c front-ended by the flow switch 110. In this case, the FAC is asked to assign a flow for servicing the content request to a local server, chosen from among the list of candidate servers returned by the CSD (step 408). If the FAC successfully assigns the flow to a local server (decision step 412), then an appropriate network address translation for the flow is set up (step 416), a connection is set up with the appropriate server (using a pre-cached, persistent, or newly created connection) (step 426), and the content request is passed to the server (step 428).

If the CSD is unable to identify any local servers to serve the content request (decision step 406), or if the FAC is unable to assign a flow for the content request to a local server (decision step 412), then if the status indicator (returned by either the CSD in step 404 or the FAC in step 408) indicates that the flow should be redirected to a remote server (step 410), then the flow is redirected to a remote server (step 414). If the CSD indicated (in step 404) that the flow should be spoofed (decision step 418), then the client TCP request is spoofed (step 420). If the flow cannot be assigned to any server, then the flow is rejected with an appropriate error (step 422).

Referring to FIG. 4, the CSD parses a flow setup request as follows. First, the CSD parses the URI representing the client content request in order to identify the nature of the requested content (step 429). If the request is an HTTP request, for example, elements of the HTTP header, including the HTTP content-type, are extracted. In the case of a non-HTTP request, the combination of protocol number and source/destination port are used to identify the nature of the requested content. In the case of an HTTP request, the content-type or filename extension is used to deduce a QoS class, delay, minimum bandwidth, and frame loss ratio as shown in Table 1, below. The content-size is used to determine the size of the requested flow. Overall flow intensity is monitored by the content-aware flow switch 110 by calculating the average throughput of all flows. The degree to which a particular piece of content served by a server is "hot content" is measured by monitoring the number of hits (requests) the content receives. The burstiness of a flow is determined by calculating the number of flows per content per time unit.

Identifying the nature of the requested content also involves deducing, from the content request and information stored in the CSD, the QoS requirements of the requested content. These QoS requirements include:

Bandwidth, defined by the number of bytes of content to be transferred over the average flow duration.

Delay, defined as the maximum delay suitable for retrieving particular content.

Frame Loss Ratio, defined as the maximum acceptable percentage of frame loss tolerated by the particular type of content.

A QoS class is assigned to a flow based on the flow's calculated QoS requirements. Eight QoS classes

are supported by the flow switch 110. Table 1 indicates how these classes might be used.

| QoS Class | Delay (End to End) | Min Bandwidth | Frame Loss Ratio | Example Applications |
|---|---|---|---|---|
| 0 | N/A | N/A | $10^{-8}$ | Control Flows |
| 1 | < 250ms | 8 KBPS | $10^{-8}$ | Internet Phone |
| 2 | Interactive | 4 KBPS | $10^{-4}$ | Distance Learning, Telemetry, streaming video/audio |
| 3 | 500ms | 0-16 Mbps | $10^{-4}$ | Media distribution, multi-user games, interactive TV |
| 4 | Low | 64 KBPS | Data: $10^{-8}$ Streaming: $10^{-4}$ | Entertainment, traditional fax |
| 5 | Low | N/A | $10^{-8}$ | Stock Ticker, News |
| 6 | N/A | N/A | $10^{-8}$ | Service Distribution, Internet Printing |
| 7 | N/A/ | N/A | $10^{-4}$ | Best effort traffic (email, Internet fax, database, etc.) |

**Table 1**

After the nature of the requested content has been identified, the CSD queries its database for records of candidate servers containing the requested content (step 430). If the CSD cannot find any records in the database to satisfy a given content request (decision step 432), the ICP/IPP is asked to locate the requested content, in order to increase the probability that future requests for the requested content will be satisfied (step 446). The CSD then returns a NULL list to the WFR with a status indicator indicating that the flow request should be rejected (steps 434, 444).

If one or more matching server records are found (decision step 432) and the client request is in the form of a HTTP GET (decision step 436), then the CSD determines whether any of the existing content records exactly matches the requested content (decision step 448). For example, consider a content request for http://www.company.com/document.html. The CSD will consider a content record for http://www.company.com/* to be an exact match for the content request. The CSD will consider a record for http://www.company.com/ to be a match for the request, but not the most specific match. In the case of an exact match, the CSD sorts the list of candidate servers (identified in step 430) based on configurable preferences (step 442). In the case of at least one match but no exact matches, the CSD creates a new record containing default information extracted from the most specific matching record, as well as additional information gleaned from the content request itself (step 450). This additional information may include the QoS requirements of the flow, based on the port number of the content request, or the filename extension (e.g., ".mpg" might indicate a video clip) contained in the request. The CSD asks the ICP/IPP to probe, in the background, for more specific information to use for future requests (step 452).

If one or more server records are found (decision step 432) and the client content request is in the form of a TCP SYN (decision step 436), the mere receipt by the flow switch of a TCP SYN may not provide the CSD with enough information about the nature of the requested flow for the CSD to make a determination of which available servers can service the requested flow. For example, the TCP SYN may indicate the server to which the content request is addressed, but not indicate which specific piece of content is being requested from the server. If

receipt of a HTTP GET from the client is required to identify a server to serve the content request (decision step 438), then the CSD returns a NULL server list to the WFR with a status indicator requesting that the TCP connection be spoofed and that the subsequent HTTP GET from the client be forwarded to the CSD (step 440).

If the TCP SYN is adequate to identify a server to service the content request (decision step 438), then the CSD sorts the list of candidate servers (identified in step 430) based on configurable preferences (step 442).

If adequate information was available in the content request to generate a list of available servers (decision step 432) and the request may be serviced by one of the servers locally attached to the data switch (decision step 451), then the Client Capability Database (CCD) is queried for any available information on the capabilities of the requesting client (step 453).

Referring to FIG. 5, given a content request and a list of candidate servers, the CSD sorts the list of candidate servers as follows. If the CSD content records indicate that the requested content is "sticky" (i.e., that a client who accesses such content must remain attached to a single server for the duration of the transaction between the client and the server, which could be comprised of multiple individual content requests) (decision step 454), then the CSD searches an internal database to determine to which server this client was previously "stuck" (step 456). If the CSD finds no record for this client (decision step 458), then the CSD indicates that the request should be rejected (step 464). If the CSD finds a record of this client (decision step 458), then the CSD creates and returns a list of candidate servers which includes only the "sticky" server to which the client was previously "stuck" (step 460), and indicates that a local server to

serve the content request was found (step 462). If the requested content is not "sticky" (decision step 454), then the list of candidate servers is ordered according to the method of FIG. 6 (step 456).

Referring to FIG. 6, the CSD orders the list of candidate servers as follows. The CSD evaluates the requested content according to several criteria (step 468). The CSD filters the candidate server list and orders (sorts) the candidate servers remaining in the candidate server list (step 470). Servers in the candidate server list are assigned proximity preferences (step 472).

If the first server in the sorted list of candidate servers is a remote server (decision step 474), then the CSD assigns a value of REDIRECT to a status indicator (step 476). If the first server in the sorted list of candidate servers is a local server (decision step 474), then the CSD assigns a value of ACCEPT to the status indicator (step 478). The CSD returns the status indicator and the ordered list of candidate servers (step 480).

Referring to FIG. 7, a particular requested content is evaluated by the CSD as follows. A variable requestFlag is used to store several flags (values which can be either true or false) relating to the requested content. Flags stored in requestFlag include BURSTY (indicating whether the requested content is undergoing a burst of requests), LONG (indicating that this the request is likely to result in a long-lived flow), FREQUENT (indicating that the requested content is frequently requested), and HI_PRIORITY (indicating that the requested content is high priority content).

If the current time at which the requested content is being requested minus the previous time at which the requested content was requested is not greater than

avgInterval (the average period of time between flow requests for the requested content) (decision step 482), then a variable burstLength is assigned a value of zero (step 484) and requestFlag is assigned a value of zero (step 486). Otherwise (decision step 482), the value of the variable burstLength is incremented (step 488), and if the value of burstLength is greater than MIN_BURST_RUN (decision step 490), then avgInterval is recalculated (step 492), and the variable requestFlag is assigned a value of BURSTY (step 494). MIN_BURST_RUN is a configurable value which indicates how many sub-avgInterval requests for a given piece of content constitute the beginning of a burst.

A variable runTime is set equal to the current time (step 496). A flag requestFlag is used to store several pieces of information describing the requested content. If the size of the requested content is greater than a predetermined constant SMALL_CONTENT (decision step 498), then the LONG flag in requestFlag is set (step 502). If the requested content is streamed (decision step 500), then the LONG flag in requestFlag is set (step 502). If the number of hits the requested content has received is greater than a predetermined constant HOT_CONTENT (decision step 504), then the FREQUENT flag in requestFlag is set (step 506). If the requested content has previously been flagged as HIGH_PRIORITY (decision step 508), then the HI_PRIORITY flag in requestFlag is set (step 510).

Referring to FIG. 8, the CSD assigns status indicators to the servers in the candidate server list as follows. The first server in the candidate server list is selected (step 514). If the selected server should be filtered (decision step 516), then the selected server is removed from the candidate server list (step 518). Otherwise, the server is evaluated (step 520), and

ordering rules are applied to the selected server to assign a status indicator to the selected server (step 522). If there are more servers in the candidate server list (decision step 524), then the next server in the candidate server list is selected (step 526), and steps 516-524 are repeated. Otherwise, assignment of status indicators to the servers in the candidate server list is complete (step 528).

Referring to FIG. 9, servers are filtered from the candidate server list as follows. If a server has not responded to recent queries (decision step 530), is no longer reachable due to a network topology change (decision step 532), or no longer contains the requested content (indicated by an HTTP 404 error in response to a request for the requested content), then the server is flag for removal from the candidate server list (step 536).

Referring to FIG. 10, a server in the candidate server list is evaluated as follows. A variable serverFlag is used to store several flags relating to the server. Flags stored in serverFlag include RECENT_THIS (indicating that a request was recently made to the server for the same content as is being requested by the current content request), RECENT_OTHER (indicating that a request was recently made to the server for content other than the content being requested by the current content request), RECENT_MANY (indicating that many distinct requests for content have recently been made to the server), LOW_BUFFERS (set to TRUE when one or more recent requests have been streamed), RECENT_LONG (indicating that one or more of the server's recent flows was long-lived), LOW_PORT_BW (indicating that the server's port bandwidth is low), and LOW_CACHE (indicating that the server is low on cache resources).

If the server was not recently accessed (decision step 540), then none of the flags in serverFlag are set, and evaluation of the server is complete (step 570). Otherwise, if the server was recently accessed for the same content as is being requested by the current content request (decision step 542), then serverFlag is assigned a value of RECENT_THIS (step 546); otherwise, serverFlag is assigned a value of RECENT_OTHER (step 548). If there have been many recent distinct requests to the server (decision step 550), then the RECENT_MANY flag in serverFlag is set (step 552). If any of the recent requests to the server were streamed (decision step 554), then the LOW_BUFFERS flag of serverFlag is set (step 556). If any of the recent requests to the server were long-lived (decision step 558), then the RECENT_LONG flag of serverFlag is set (step 560). If the port bandwidth of the server is low (decision step 562), then the LOW_PORT_BW flag of serverFlag is set (step 564). If the RECENT_OTHER flag of serverFlag is set (decision step 566), then the LOW_CACHE flag of serverFlag is set (step 568).

Referring to FIG. 11, a server in the candidate server list is ordered within the candidate server list as follows. A variable Status is used to indicate whether the server should be placed at the bottom of the candidate server list. Specifically, if the HI_PRIORITY flag of requestFlag is set (decision step 572), then Status is assigned a value according to FIG. 12 (step 574). If the BURSTY flag of requestFlag is set (decision step 576), then Status is assigned a value according to FIG. 13 (step 578). If the FREQUENT flag of requestFlag is set (decision step 580), then Status is assigned a value according to FIG. 14 (step 582). If the LONG flag of requestFlag is set (decision step 584), then Status assigned a value according to FIG. 15 (step 586);

otherwise, Status is assigned a value according to FIG. 16 (step 588). If the value of Status is not OKAY (decision step 590), then the server is considered not optimal and is placed at the bottom of the candidate server list (step 584). Otherwise, the server is considered adequate and is not moved within the candidate server list (step 592).

Referring to FIG. 12, in the case of a request for a flow for which the HI_PRIORITY flag of requestFlag is set, if the LOW_CACHE flag of serverFlag is set (decision step 596), the RECENT_OTHER flag of serverFlag is set (decision step 598), the LOW_PORT_BW flag of serverFlag is set (decision step 600), or the RECENT_LONG flag of serverFlag is set (decision step 602), then Status is assigned a value of NOT_OPTIMAL (step 608). Otherwise, Status is assigned a value of OKAY (step 604).

Referring to FIG. 13, in the case of a request for a flow for which the BURSTY requestFlag is set and the RECENT_THIS serverFlag is not set (decision step 608), and if either the LOW_CACHE or RECENT_MANY serverFlag is set (decision steps 610 and 612), then Status is assigned a value of NOT_OPTIMAL (step 616). Otherwise, Status is assigned a value of OKAY (step 614).

Referring to FIG. 14, a value is assigned to Status in the case of a request for a flow which is not bursty and not frequently requested as follows. Status is assigned a value of NOT_OPTIMAL (step 644) if any of the following conditions obtain: (1) the LONG flag of requestFlag is set and the LOW_BUFFERS and LOW_CACHE flags of serverFlag are set (decision steps 620, 622, and 624); (2) the RECENT_MANY, RECENT_THIS, and LOW_CACHE flags of serverFlag are set (decision steps 626, 628, and 630); (3) the RECENT_LONG, RECENT_THIS, and LOW_CACHE flags of serverFlag are set (decision steps 632, 634, and 636); or (4) the LONG flag of requestFlag is set and the

LOW_PORT_BW flag of serverFlag is set (decision steps 638 and 640). Otherwise, Status is assigned a value of OKAY (step 642).

Referring to FIG. 15, a value is assigned to Status in the case of a request for a flow which is non-bursty, frequently requested, and short-lived as follows. Status is assigned a value of NOT_OPTIMAL (step 664) if any of the following conditions obtain: (1) the LOW_BUFFERS and LOW_CACHE flags of serverFlag are set (decision steps 646, 648); (2) the RECENT_LONG, RECENT_OTHER, and LOW_CACHE flags of serverFlag are set (decision steps 650, 652, and 654); or (3) the RECENT_MANY, RECENT_OTHER, and LOW_CACHE flags of serverFlag are set (decision steps 656, 658, and 660). Otherwise, Status is assigned a value of OKAY (step 662).

Referring to FIG. 16, a value is assigned to Status in the case of request for flows which are not handled by any of FIGS. 12-15 as follows. Status is assigned a value of NOT_OPTIMAL (step 680) if any of the following conditions obtain: (1) the LOW_BUFFERS and LOW_CACHE flags of serverFlag are set (decision steps 666, 668); (2) the RECENT_MANY and LOW_CACHE flags of serverFlag are set (decision steps 67 and 672); or (3) the RECENT_LONG and LOW_PORT_BW flags of serverFlag are set (decision steps 674 and 676). Otherwise, Status is assigned a value of OKAY (step 678).

Referring again to FIG. 6, the servers remaining in the candidate server list are sorted again, this time by proximity to the client making the content request (step 472). The details of sorting by proximity are discussed in more detail below with respect to the Internet Proximity Assist (IPA) and with respect to FIG. 22.

The first server in the candidate server list is examined, and if it is local to the content-aware flow switch 110 (decision step 474), then a variable Status is

assigned a value of ACCEPT (step 478), indicating that the content-aware flow switch 110 can service the requested flow using a local server. Otherwise, Status is assigned a value of REDIRECT (step 476), indicating that the flow request should be redirected to a remote server.

The process of deciding whether to create a flow in response to a client content request is referred to as Flow Admission Control (FAC). Referring again to FIG.3, if the value of Status is ACCEPT (decision step 406), then the FAC is asked to assign the requested flow to a local server (step 408). The FAC admits flows into the flow switch 110 based on flow QoS requirements and the amount of link bandwidth, flow switch bandwidth, and flow switch buffers. Flow admission control is performed for each content request in order to verify that adequate resources exist to service the content request, and to offer the content request the level of service indicated by its QoS requirements. If sufficient resources are not available, the content request may be redirected to another site capable of servicing the request or simply be rejected.

More specifically, referring to FIG. 17, the FAC assigns a flow to a local server from among an ordered list of candidate servers, in response to a content request, as follows. First, the FAC fetches the first server record from the list of candidate servers (step 684). If the server record is for a local server (decision step 686), and the local server can satisfy the content request (decision step 690), then the FAC indicates that the content request has been successfully assigned to a local server (step 694). If the server record is not for a local server (decision step 686), then the FAC indicates that the content request should be redirected (step 688).

If the server record is for a local server (decision step 686) that cannot satisfy the content request (decision step 690), and there are more records in the list of candidate servers to evaluate (decision step 696), then the FAC evaluates the next record in the list of candidate servers (step 698) as described above. If all of the records have been evaluated without redirecting the request or assigning the request to a local server, then the content request is rejected, and no flow is set up for the content request (step 700).

Referring to FIG. 18, the FAC attempts to establish a flow between a client and a candidate server, in response to a client content request, as follows. The FAC extracts, from the CSD server record for the candidate server, the egress port of the flow switch to which the candidate server is connected. The FAC also extracts, from the content request, the ingress port of the flow switch at which the content request arrived (step 726). Using the information obtained in step 726 and other information from the candidate server record, the FAC constructs one or more QoS tags (step 728). A QoS tag encapsulates information about the deduced QoS requirements of an existing or requested flow.

If the requested content is not served by a (physical or virtual) web host associated with a flow pipe (decision step 730), then the FAC attempts to add the requested flow to an existing VC pipe (step 732). A VC pipe is a logical aggregation of flows sharing similar characteristics; more specifically, all of the flows aggregated within a single VC pipe share the same ingress port, egress port, and QoS requirements. Otherwise, the FAC attempts to add the requested flow to the flow pipe associated with the server identified by the candidate server record (step 734). Once the QoS requirements of a flow have been calculated, they are stored in a QoS tag,

so that they may be subsequently accessed without needing to be recalculated.

Referring to FIG. 19, the FAC constructs a QoS tag from a candidate server record, ingress and egress port information, and any available client information, as follows. If the requested content is not to be delivered using TCP (decision step 738), then the FAC calculates the minimum bandwidth requirement MinBW of the requested content based on the total bandwidth PortBW available to he logical egress port of the flow and the hop latency hopLatency (a static value contained in the candidate server record) of the flow, using the formula:

MinBW = frameSize / hopLatency)

**Formula 1**

(step 756). If the requested content is to be delivered using TCP (decision step 738), then the FAC calculates the average bandwidth requirement AvgBW of the requested flow based on the size of the candidate server's cache CacheSize (contained in the candidate server record), the TCP window size TcpW (contained in the content request), and the round trip time RTT (determined during the initial flow handshake), using the formula:

AvgBW = min(CacheSize, TcpW) / RTT

**Formula 2**

(step 740). The FAC uses the average bandwidth AvgBW and the flow switch latency (a constant) to determine the minimum bandwidth requirement MinBW of the requested content using the formula:

MinBW = min(AvgBW * MinToAvg, clientBW)

**Formula 3**

In Formula 3, MinToAvg is the flow switch latency and clientBW is derived from the maximum segment size (MSS) option of the flow request (step 742).

The content-aware flow switch 110 reserves a fixed amount of buffer space for flows. The FAC is responsible for calculating the buffer requirements (stored in the variable Buffers) of both TCP and non-TCP flows, as follows. If the requested flow is not to be streamed (decision step 744), then the flow is provided with a best-effort level of buffers (step 758). Streaming is typically used to deliver real-time audio or video, where a minimum amount of information must be delivered per unit of time. If the content is to be streamed (decision step 744), then the burst tolerance btol of the flow is calculated (step 746), the peak bandwidth of the flow is calculated (step 748), and the buffer requirements of the flow are calculated (step 750). A QoS tag is constructed containing information derived from the calculated minimum bandwidth requirement and buffer requirements (step 752). The FAC searches for any other similar existing QoS tags that sufficiently describe the QoS requirements of the requested content (step 754).

Referring to FIG. 20, the FAC locates any existing QoS tags which are similar enough (in MinBW and Buffers) to the QoS tag constructed in FIG. 19 to be acceptable for this content request, as follows. If the requested content is not to be delivered via TCP (decision step 764), then the FAC finds all QoS tags with a higher minimum bandwidth requirement but with lower buffer requirements than the given QoS tag (step 766). If the content is to be delivered via TCP (decision step 764), then the FAC finds all QoS tags with a lower minimum bandwidth requirement and higher buffer requirements than the given QoS tag (step 768). If the requested content is not to be streamed (decision step 770), then for each

existing QoS tag, the FAC calculates the average bandwidth, calculates the TCP window size as TcpW = AvgBW * RTT, and verifies that the TCP window size is at least 4K (the minimum requirement for HTTP transfers) (step 774). If the requested content is to be streamed (decision step 770), then the FAC examines each existing QoS tag and excludes those that are not capable of delivering the required peak bandwidth PeakBW or burst tolerance btol, as calculated in FIG. 19, steps 746 and 748 (step 772). The resulting list of QoS tags is then used when aggregating the flow into a VC-pipe or flow pipe.

One of the effects of the procedures shown in FIGS. 3-20 is that the flow switch 110 functions as a network address translation device. In this role, it receives TCP session setup requests from clients, terminates those requests on behalf of the servers, and initiates (or reuses) TCP connections to the best-fit target server on the client's behalf. For that reason, two separate TCP sessions exist, one between the client and the flow switch, the other between the flow switch and the best-fit server. As such, the IP, TCP, and possible content headers on packets moving bidirectionally between the client and server are modified as necessary as they traverse the content-aware flow switch 110.

**Flow Pipes**

A content-aware flow switch can be used to front-end many web servers. For example, referring to FIG. 1c, the flow switch 110 front-ends web servers 100a-c. Each of the physical web servers 100a-c may embody one or more virtual web hosts (VWH's). Associated with each of the VWH's front-ended by the flow switch 110 may be a "flow pipe," which is a logical aggregation of the VWH's flows. Flow pipes guarantee an individual VWH a configurable

amount of bandwidth through the content-aware flow switch 110.

Referring to FIG. 21a, web servers 100a-c provide service to VWHs 100d-f as follows. Web server 100a provides all services to VWH 100d. Web server 100b provides service to VWH 100e and a portion of the services to VWH 100f. Web server 100c provides service to the remainder of VWH 100f. Associated with VWHs 100d-f are flow pipes 784a, 784b, and 784c, respectively. Note that flow pipes 784a-c are logical entities and are therefore not shown in FIG. 21a as connecting to VWH's 100d-f or the flow switch 110 at physical ports.

The properties of each of the VWH's 100d-f is configured by the system administrator. For example, each of the VWH's 100d-f has a bandwidth reservation. The flow switch 110 uses the bandwidth reservation of a VWH to determine the bandwidth to be reserved for the flow pipe associated with the VWH. The total bandwidth reserved by the flow switch 110 for use by flow pipes, referred to as the flow pipe bandwidth, is the sum of all the individual flow pipe reservations. The flow switch 110 allocates the flow pipe bandwidth and shares it among the individual flow pipes 784a-c using a weighted round robin scheduling algorithm in which the weight assigned to an individual flow pipe is a percentage of the overall bandwidth available to clients. The flow switch 110 guarantees that the average total bandwidth actually available to the flow pipe at any given time is not less than the bandwidth configured for the flow pipe regardless of the other activity in the flow switch 110 at the time. Individual flows within a flow pipe are separately weighted based on their QoS requirements. The flow switch 110 maintains this bandwidth guarantee by proportionally adjusting the weights of the individual flows in the flow pipe so that the sum of the weights

remains constant. By policing against over-allocation of bandwidth to a particular VWH, fairness can be achieved among the VWH's competing for outbound bandwidth through the flow switch 110.

Again referring to FIG. 21a, consider the case in which the flow switch 110 is configured to provide service to three VWH's 100d-f. Suppose that the bandwidth requirements of VWH100d-f are 64Kbps, 256Kbps, and 1.5Mbps, respectively. The total flow pipe bandwidth reserved by the flow switch 110 is therefore 1.82Mbps. Assume for purposes of this example that the flow switch 110 is connected to the Internet by uplinks 115a-c with bandwidths of 45Mbps, 1.5Mbps, and 1.5Mbps, respectively, providing a total of 48Mbps of bandwidth to clients. In this example, flow pipe 784a is assigned a weight of .0013 (64Kbps/48Mbps), flow pipe 784b is assigned a weight of .0053 (256Kbps/48Mbps), and flow pipe 784c is assigned a weight of .0312 (1.5Mbps/48Mbps). As individual flows within flow pipes 784a-c are created and destroyed, the weights of the individual flows are adjusted such that the total weight of the flow pipe is held constant.

The relationship between flows, flow pipes, and the physical ingress ports 170a-c and physical egress ports 165a-c of the content-aware flow switch 110 is discussed below in connection with FIG. 21b. Flows 782a-c from VWH 100d enter the flow switch at egress port 165a. Flows 786a-b from VWH 100c enter the flow switch at egress port 165b. Flow 786c from VWH 100f enters the flow switch at egress port 165b. Flows 788a-c from VWH 100f enters the flow switch from egress port 165c. After entering the flow switch 110, the flows 782a-c, 786a-c, and 788a-c are managed within their respective flow pipes 784a-c as they pass through the switching matrix 790. The switching matrix is a logical entity that associates a logical

ingress port and a logical egress port with each of the flows 782a-c, 786a-c, and 788a-c. As previously mentioned, each of the physical ingress ports 170a-c may act as one or more logical ingress ports, and each of the physical egress ports 165a-c may act as one or more logical egress ports. FIG. 21b shows a possible set of associations of physical ingress ports with flow pipes and physical egress ports for the flows 782a-c, 786a-c, and 788a-c.

**Internet Proximity Assist**

A client may request content that is available from several candidate servers. In such a case, the Internet Proximity Assist (IPA) module of the content-aware flow switch 110 assigns a preference to servers which are determined to be "closest" to the client, as follows.

The Internet is composed of a number of independent Autonomous Systems (AS's). An Autonomous System is a collection of networks under a single administrative authority, typically an Internet Service Provider (ISP). The ISPs are organized into a loose hierarchy. A small number of "backbone" ISPs exist at the top of the hierarchy. Multiple AS's may be assigned to each backbone service provider. Backbone service providers exchange network traffic at Network Access Points (NAPs). Therefore, network congestion is more likely to occur when a data stream must pass through one or more NAPs from the client to the server. The IPA module of the content-aware flow switch 110 attempts to decrease the number of NAPs between a client and a server by making an appropriate choice of server.

The IPA uses a continental proximity lookup table which associates IP addresses with continents as follows. Most IP address ranges are allocated to continental registries. The registries, in turn, allocate each of the address ranges to entities within a particular

continent. The continental proximity lookup table may be implemented using a Patricia tree which is built based on the IP address ranges that have been allocated to various continental registries. The tree can then be searched using the well-known Patricia search algorithm. An IP address is used as a search key. The search results in a continent code, which is an integer value that represents the continent to which the address is registered. Given the current allocations of IP addresses, the possible return values are shown in Table 2.

| ID | Continent |
|---|---|
| 0 | Unknown |
| 1 | Europe |
| 2 | North America |
| 3 | Central and South America |
| 4 | Pacific Rim |

**Table 2**

Additional return values can be added as IP addresses are allocated to new continental registries. Given the current allocation of addresses, the continental proximity table used by the IPA is shown in Table 3.

| IP ADDRESS RANGE | CONTINENT IDENTIFIER |
|---|---|
| 0.0.0.0 through 192.255.255.255 | 0 (Unknown) |
| 193.0.0.0 through 195.255.255.255 | 1 (Europe) |
| 196.0.0.0 through 197.255.255.255 | 0 (Unknown) |
| 198.0.0.0 through 199.255.255.255 | 2 (North America) |
| 200.0.0.0 through 201.255.255.255 | 3 (Central and South America) |
| 202.0.0.0 through 203.255.255.255 | 4 (Pacific Rim) |
| 204.0.0.0 through 209.255.255.255 | 2 (North America) |
| 210.0.0.0 through 211.255.255.255 | 4 (Pacific Rim) |
| 212.0.0.0 through 223.255.255.255 | 0 (Unknown) |

**Table 3**

Referring to FIG. 22, the IPA assigns proximity preferences to zero or more servers, from a list of candidate servers and a client content request, as follows. The IPA identifies the continental location of the client (step 800). If the client continent is not known (decision step 801), then control passes to step 812, described below. Otherwise, the IPA identifies the continental location of each of the candidate servers (step 802) using the continental proximity lookup table, described above. If all of the server continents are unknown (decision step 803), control passes to step 807, described below. Otherwise, if none of the candidate servers are in the same continent as the client (decision step 804), then the IPA does not assign a proximity preference to any of the candidate servers (step 806).

At step 807, the IPA prunes the list of candidate servers to those which are either unknown or in the same continent as the client. If there is exactly one server

in the same continent as the client (decision step 808), then the server in the same continent as the client is assigned a proximity preference (decision step 810). For purposes of decision steps 804 and 808, a client and a server are considered to reside in the same continent if their lookup results match and the matching value is not 0 (unknown).

If there is more than one server in the same continent as the client (decision step 808), then the IPA assigns a proximity preference to one or more servers, if any, which share a "closest" backbone ISP with the client, where "closest" means that the backbone ISP can reach the client without going through another backbone ISP. A closest-backbone lookup table, which may be implemented using a Patricia tree, stores information about which backbone AS's are closest to each range of IP addresses. An IP address is used as the key for a search in the closest-backbone lookup table. The result of a search is a possibly empty list of AS's which are closest to the IP address used as a search key.

The IPA performs a query on the closest-backbone lookup table using the client's IP address to obtain a possibly empty list of the AS's that are closest to the client (step 812). The IPA queries the closest-backbone lookup table to obtain the AS's which are closest to each of the candidate servers previously identified as being in the same continent as the client (step 814). The IPA then identifies all candidate servers whose query results contain an AS that belongs to the same ISP as any AS resulting from the client query performed in step 812 (step 816). Each of the servers identified in step 816 is then assigned a proximity preference (step 818).

After any proximity preferences have been assigned in either step 810 or 818, the existence of a network path between the client and each of the preferred servers

is verified (step 820). To verify the existence of a network path between the client and a server, the content-aware flow switch 110 queries the content-aware flow switch that front-ends the server. The remote content-aware flow switch either does a Border Gateway Protocol (BGP) route table lookup or performs a connectivity test, such as by sending a PING packet to the client, to determine whether a network path exists between the client and the server. The remote content-aware flow switch then sends a message to the content-aware flow switch 110 indicating whether such a path exists. Any server for which the existence of a network path cannot be verified is not assigned a proximity preference. Servers to which a proximity preference has been assigned are moved to the top of the candidate server list (step 822).

Because multiple AS's may be assigned to a single ISP, an ISP-AS lookup table is used to perform step 816. The ISP-AS lookup table is an array in which each element associates an AS with an ISP. An AS is used as a key to query the table, and the result of a query is the ISP to which the key AS is assigned.

Referring to FIG. 23, the invention may be implemented in digital electronic circuitry or in computer hardware, firmware, software, or in combinations of them. Apparatus of the invention may be implemented in a computer program product tangibly embodied in a machine-readable storage device for execution by a computer processor 1080; and method steps of the invention may be performed by a computer processor 1080 executing a program to perform functions of the invention by operating on input data and generating output. The processor 1080 receives instructions and data from a read-only memory (ROM) 1120 and/or a random access memory (RAM) 1110 through a CPU bus 1100. The processor 1080

can also receive programs and data from a storage medium such as an internal disk 1030 operating through a mass storage interface 1040 or a removable disk 1010 operating through an I/O interface 1020. The flow of data over an I/O bus 1050 to and from I/O devices and the processor 1080 and memory 1110, 1120 is controlled by an I/O controller 1090.

The present invention has been described in terms of an embodiment. The invention, however, is not limited to the embodiment depicted and described. Rather, the scope of the invention is defined by the claims.

What is claimed is:

1. In an Internet Protocol network, a method for directing a flow between a client and a best-fit server, the method comprising:

receiving a client request for content via the Internet Protocol network;

deriving, from the client request, content type information descriptive of the type of content requested by the content request;

deriving, from the client request, quality of service information descriptive of quality of service requirements of the content requested by the client request;

selecting as the best-fit server a server from among a set of candidate servers serving the content requested by the client request, based on the content type information, the quality of service information, and a combination of server metrics descriptive of expected qualities of service provided by the candidate servers when serving the requested content;

subsequently forwarding to the best-fit server transmissions originating from the client which are associated with the client request for content; and

subsequently forwarding to the client transmissions originating from the best-fit server which are associated with the client request for content.

2. The method of claim 1, wherein the combination of server metrics includes:

one or more metrics selected from the following group: server load metrics descriptive of the current load and recent activity on the candidate servers, network congestion metrics descriptive of network congestion between the client and the candidate servers,

and client-server proximity information descriptive of distances between the client and candidate servers.

3. The method of claim 1, wherein the combination of server metrics includes:

two or more metrics selected from the following group: server load metrics descriptive of the current load and recent activity on the candidate servers, network congestion metrics descriptive of network congestion between the client and the candidate servers, and client-server proximity information descriptive of distances between the client and candidate servers.

4. The method of claim 1, wherein the combination of server metrics includes:

server load metrics descriptive of the current load and recent activity on the candidate servers, network congestion metrics descriptive of network congestion between the client and the candidate servers, and client-server proximity information descriptive of distances between the client and candidate servers.

5. The method of claim 1, wherein the step of deriving quality of service information includes deriving quality of service information from the content type information.

6. The method of claim 1, wherein the step of deriving quality of service information includes deriving quality of service information from a size of the content requested by the client request.

7. The method of claim 1, wherein the client request is an HTTP request.

8. The method of claim 7, wherein deriving content type information comprises:

extracting content type information from an HTTP header of the client request.

9. The method of claim 1, wherein the client request is a TCP request.

10. The method of claim 1, further comprising:

obtaining additional information from the client about the content requested by the client request; and

wherein the selecting step further comprises selecting the best-fit server based on the additional information.

11. The method of claim 10, wherein the additional information comprises information derived from an HTTP GET.

12. The method of claim 10, wherein the obtaining step comprises obtaining a protocol number and a source port of the client request.

13. The method of claim 10, wherein the obtaining step comprises obtaining a protocol number and a destination port of the client request.

14. The method of claim 10, wherein the obtaining step comprises obtaining a filename associated with the content request.

15. The method of claim 10, wherein the obtaining step comprises obtaining a filename extension associated with the content request.

16. The method of claim 1, wherein the server metrics are obtained by querying a content server database.

17. The method of claim 1, wherein the server metrics are obtained by periodically querying servers in the Internet Protocol network.

18. The method of claim 1, further comprising:

obtaining client capability information about the client; and

wherein the selecting step further comprises selecting the best-fit server based on the additional information.

19. The method of claim 1, wherein quality of service requirements comprise a bandwidth.

20. The method of claim 1, wherein quality of service requirements comprise a delay.

21. The method of claim 1, wherein quality of service requirements comprise a frame loss ratio.

22. The method of claim 1, wherein deriving quality of service information comprises deriving quality of service information from the MIME content type of the client request.

23. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the candidate server is receiving a burst of requests for the content requested by the client request.

24. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether satisfying the client request will result in a short-term flow.

25. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the content requested by the client request has been frequently requested in the past.

26. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the content requested by the client request has a high priority.

27. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of a probability that the content requested by the client request is cached by the server.

28. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the candidate server has responded to recent queries.

29. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the candidate server recently responded to a request for the content requested by the client request

with an indication that the content is not served by the candidate server.

30. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the candidate server is reachable.

31. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the candidate server's cache resources are below a threshold level.

32. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the candidate server's TCP buffer resources are below a threshold level.

33. The method of claim 1, wherein the expected quality of service provided by a candidate server is descriptive of whether the candidate server's port bandwidth is below a threshold level.

34. The method of claim 2, wherein client-server proximity information comprises information descriptive of a continent in which the client resides and a continent in which the server resides.

35. The method of claim 34, wherein client-server proximity information further comprises information descriptive of an administrative authority associated with the client and an administrative authority associated with the server.

36. The method of claim 35, wherein the administrative authorities are Internet Service Providers.

37. The method of claim 1, wherein selecting as the best-fit server comprises:

determining whether the client request requires persistent connectivity with a particular candidate server;

if the client request requires persistent connectivity with a particular server, identifying a

candidate server with which the client is persistently connected for service of the client request;

selecting the identified candidate server as the best-fit server.

38. A method for allocating bandwidth of a data switching device to each of a plurality of flow pipes, comprising:

allocating to the plurality of flow pipes a maximum bandwidth which is a function of the available bandwidth of the data switching device;

allocating to each of the plurality of flow pipes a maximum bandwidth which is a function of the bandwidth allocated to the plurality of flow pipes; and

ensuring that the bandwidth through the data switching device consumed by a flow pipe is no greater than the maximum bandwidth allocated to the flow pipe.

39. In an Internet Protocol network, a method for selecting a best-fit server, from among a plurality of servers, to service a client request for content, the method comprising:

identifying a location of the client;

identifying a location of each of the plurality of servers;

identifying servers that are in the same location as the client; and

selecting as the best-fit server a server from among the plurality of servers using a process which assigns a proximity preference to the identified servers.

40. The method of claim 1, further comprising determining whether an active path exists between the client and the best-fit server.

41. The method of claim 40, wherein determining whether an active path exists comprises sending a PING packet to the client.

42. The method of claim 40, wherein determining whether an active path exists comprises performing a Border Gateway Protocol route table lookup.

43. The method of claim 40, wherein the location of the client comprises a continent in which the client resides.

44. The method of claim 43, wherein the locations of the plurality of servers are continents in which the servers reside.

45. The method of claim 40, wherein identifying servers that are in the same location as the client comprises:

identifying administrative authorities associated with the client;

identifying, for each of the plurality of servers, administrative authorities associated with the server; and

identifying servers associated with an administrative authority that is associated with the client.

46. The method of claim 45, wherein the administrative authorities are Internet Service Providers.

47. A system for directing a flow between a client and a best-fit server, the system comprising:

a plurality of servers;

a flow switch coupled to the plurality of servers by an Internet Protocol network through one or more communication links, wherein the flow switch comprises:

means for receiving a client request for content via the Internet Protocol network;

means for deriving, from the client request, content type information descriptive of the type of content requested by the content request;

means for deriving, from the client request, quality of service information descriptive of quality of service requirements of the content requested by the client request;

means for selecting as the best-fit server a server from among a set of candidate servers serving the content requested by the client request, based on the content type information, the quality of service information, and a combination of server metrics descriptive of expected qualities of service provided by the candidate servers when serving the requested content;

means for subsequently forwarding to the best-fit server transmissions originating from the client which are associated with the client request for content; and

means for subsequently forwarding to the client transmissions originating from the best-fit server which are associated with the client request for content.

48. The system of claim 47, wherein:

the candidate servers comprise HTTP servers.

49. A flow switch in an Internet Protocol network, comprising:

means for receiving a client request for content via the Internet Protocol network;

means for deriving, from the client request, content type information descriptive of the type of content requested by the content request;

means for deriving, from the client request, quality of service information descriptive of quality of service requirements of the content requested by the client request;

means for selecting as the best-fit server a server from among a set of candidate servers serving the content requested by the client request, based on the content type information, the quality of service information, and a combination of server metrics descriptive of expected qualities of service provided by the candidate servers when serving the requested content;

means for subsequently forwarding to the best-fit server transmissions originating from the client which are associated with the client request for content; and

means for subsequently forwarding to the client transmissions originating from the best-fit server which are associated with the client request for content.

FIG. 1a

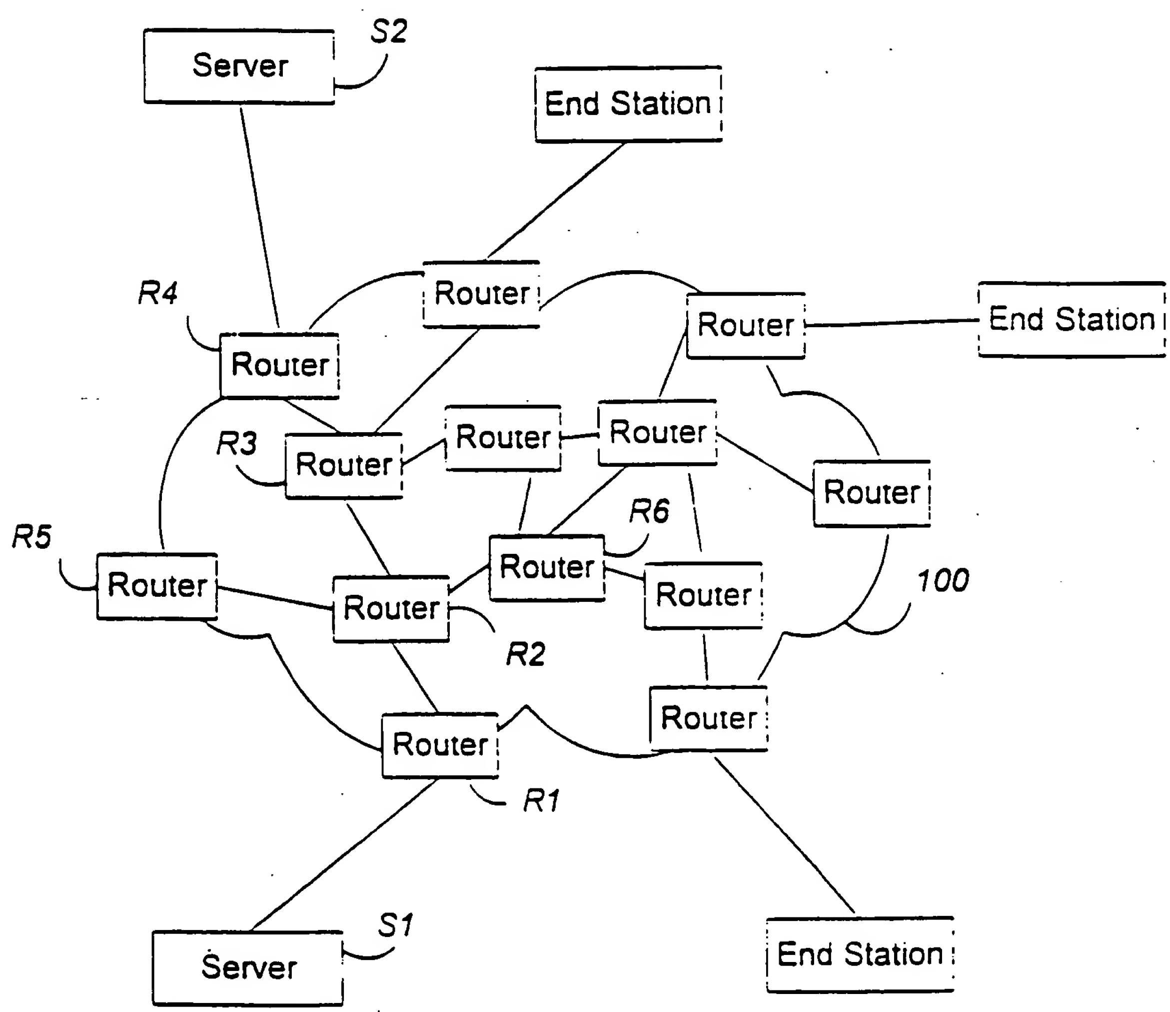
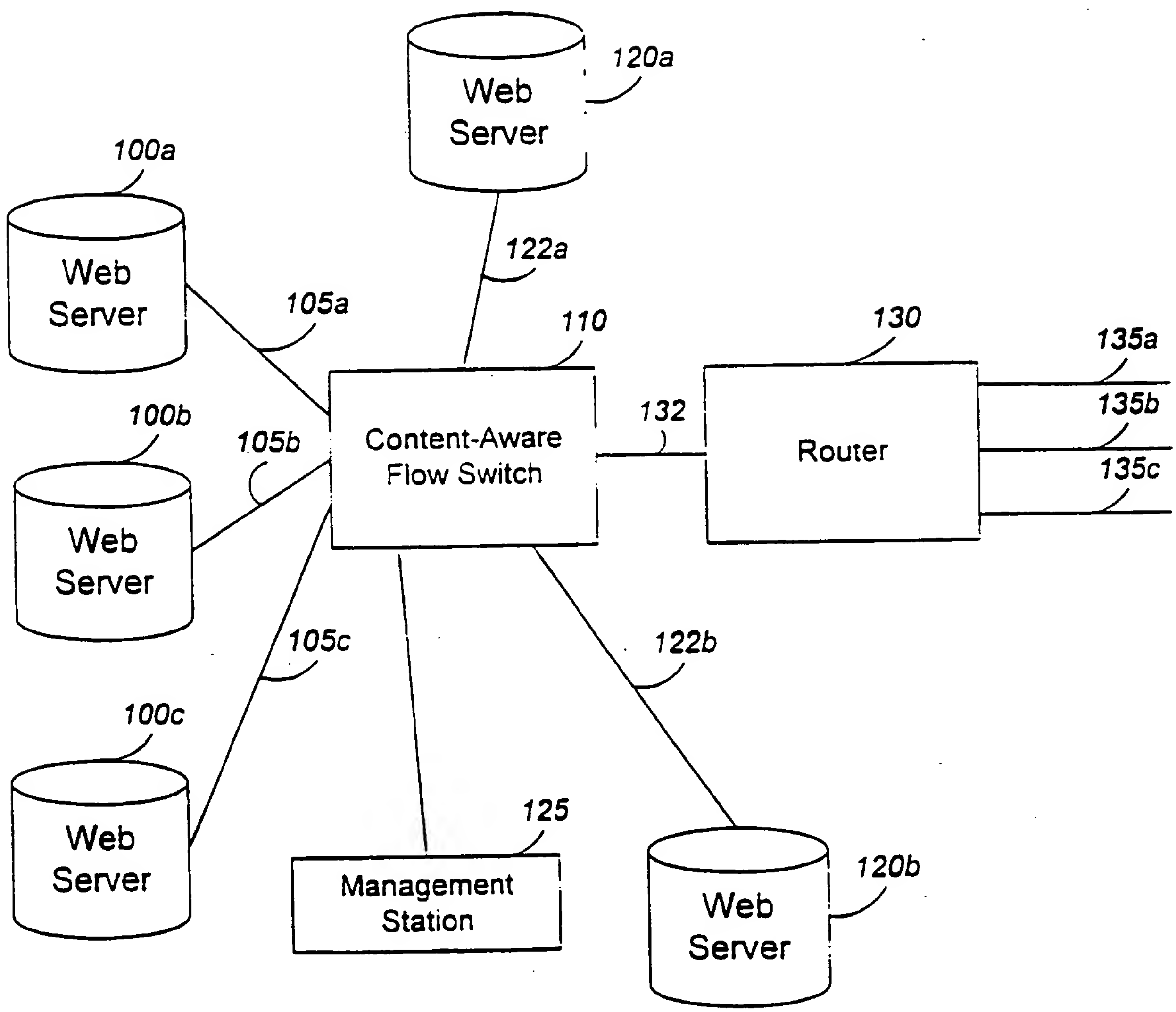

Server
S2
End Station
R4
Router
Router
Router
End Station
R3
Router
Router
Router
Router
R5
R6
Router
Router
Router
Router
100
R2
Router
Router
R1
S1
Server
End Station

FIG. 1b



Web Server
120a
100a
Web Server
122a
105a
110
130
135a
Content-Aware Flow Switch
132
Router
135b
135c
100b
105b
Web Server
105c
122b
100c
Web Server
125
Management Station
Web Server
120b

FIG. 1c

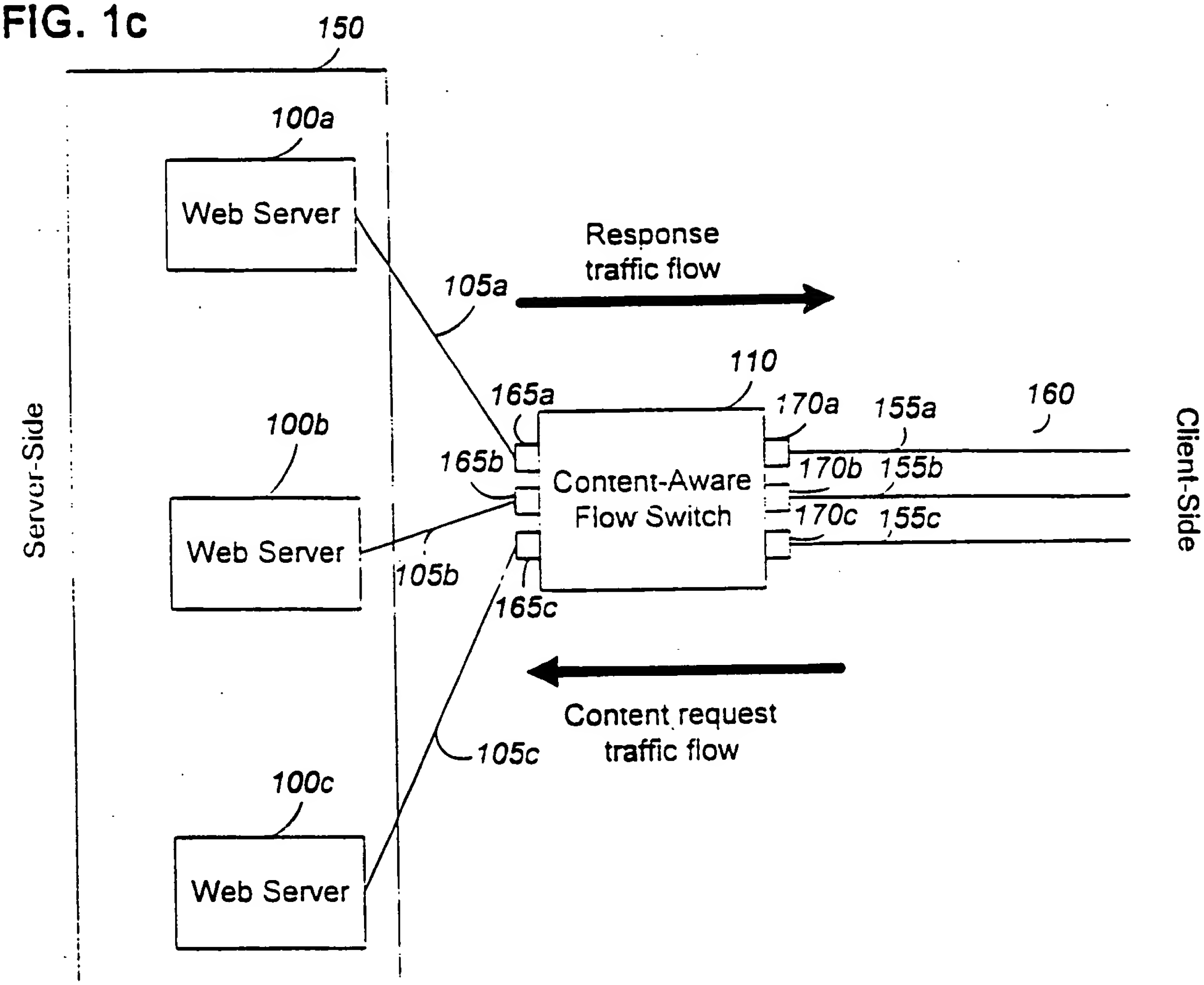

150
100a
Web Server
100b
Web Server
100c
Web Server
Server-Side
105a
105b
105c
Response traffic flow
110
165a
165b
165c
Content-Aware Flow Switch
170a
170b
170c
155a
155b
155c
160
Client-Side
Content request traffic flow

FIG. 2

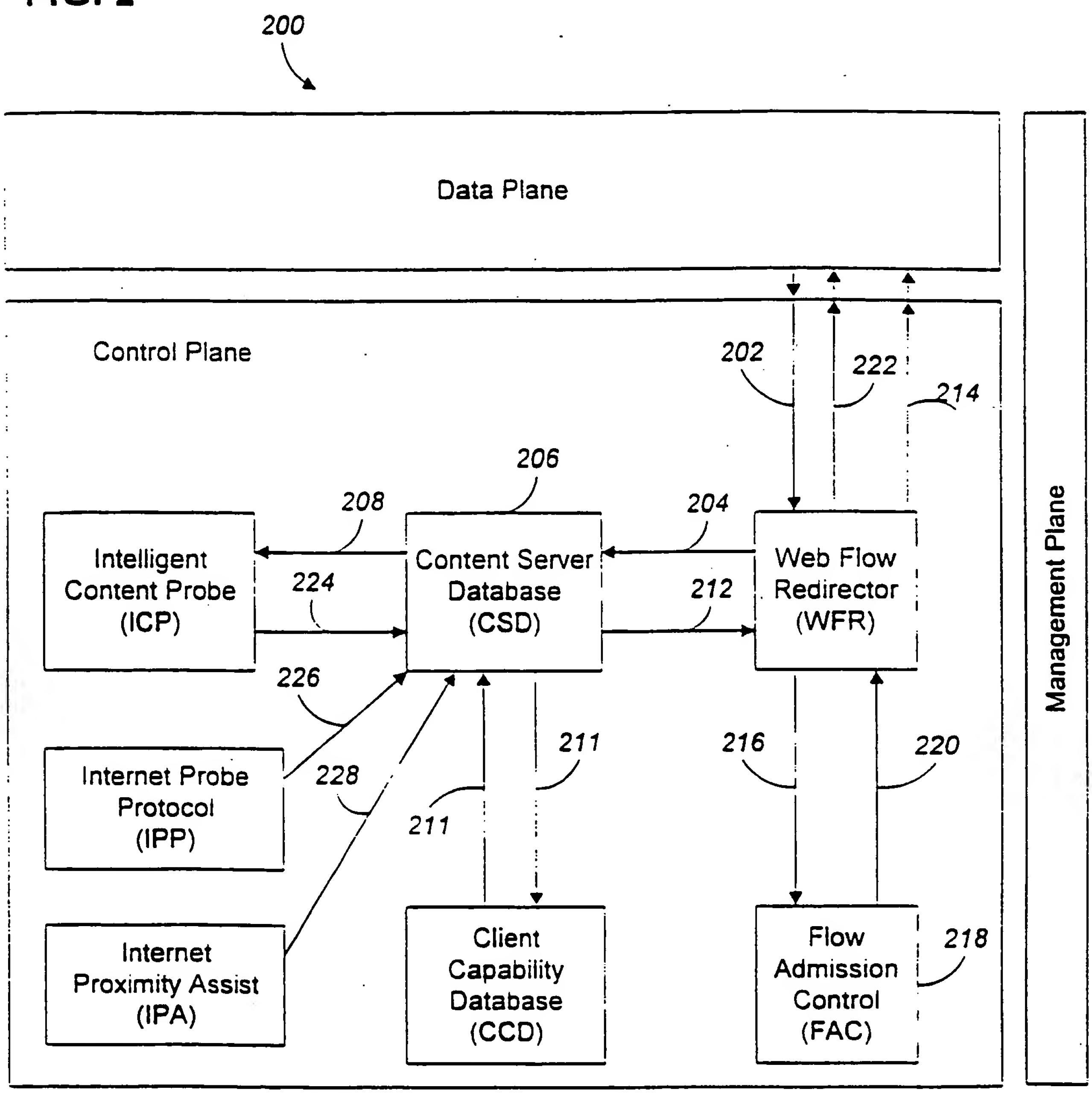
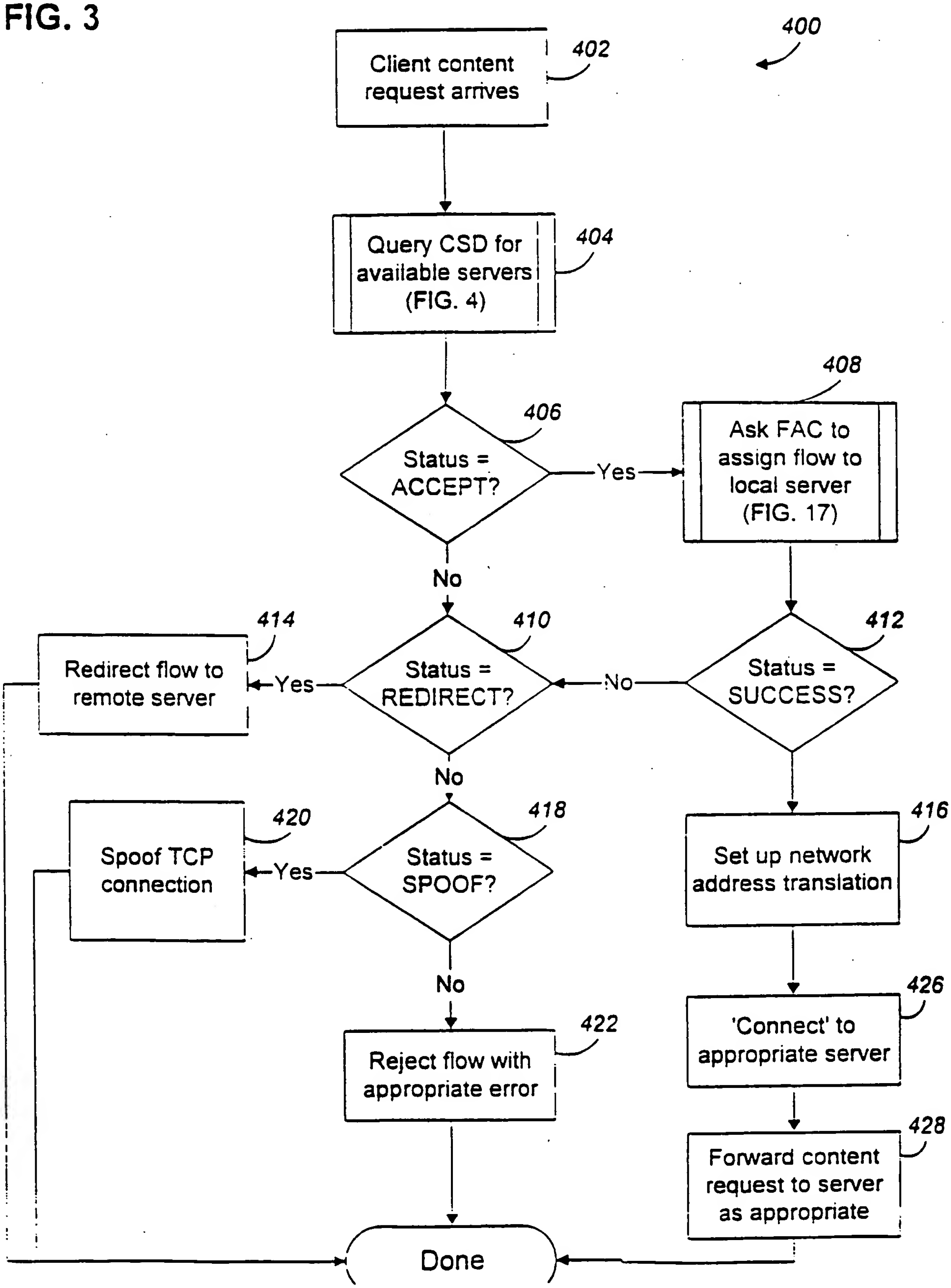

200
Data Plane
Control Plane
202
222
214
206
208
204
Intelligent Content Probe (ICP)
224
Content Server Database (CSD)
212
Web Flow Redirector (WFR)
226
211
216
220
Internet Probe Protocol (IPP)
228
211
Internet Proximity Assist (IPA)
Client Capability Database (CCD)
Flow Admission Control (FAC)
218
Management Plane

FIG. 3



400
Client content request arrives
402
Query CSD for available servers (FIG. 4)
404
Status = ACCEPT?
406
Yes
Ask FAC to assign flow to local server (FIG. 17)
408
No
Status = REDIRECT?
410
Status = SUCCESS?
412
Redirect flow to remote server
414
Yes
No
No
Status = SPOOF?
418
Spoof TCP connection
420
Yes
Set up network address translation
416
No
Reject flow with appropriate error
422
'Connect' to appropriate server
426
Forward content request to server as appropriate
428
Done

FIG. 4

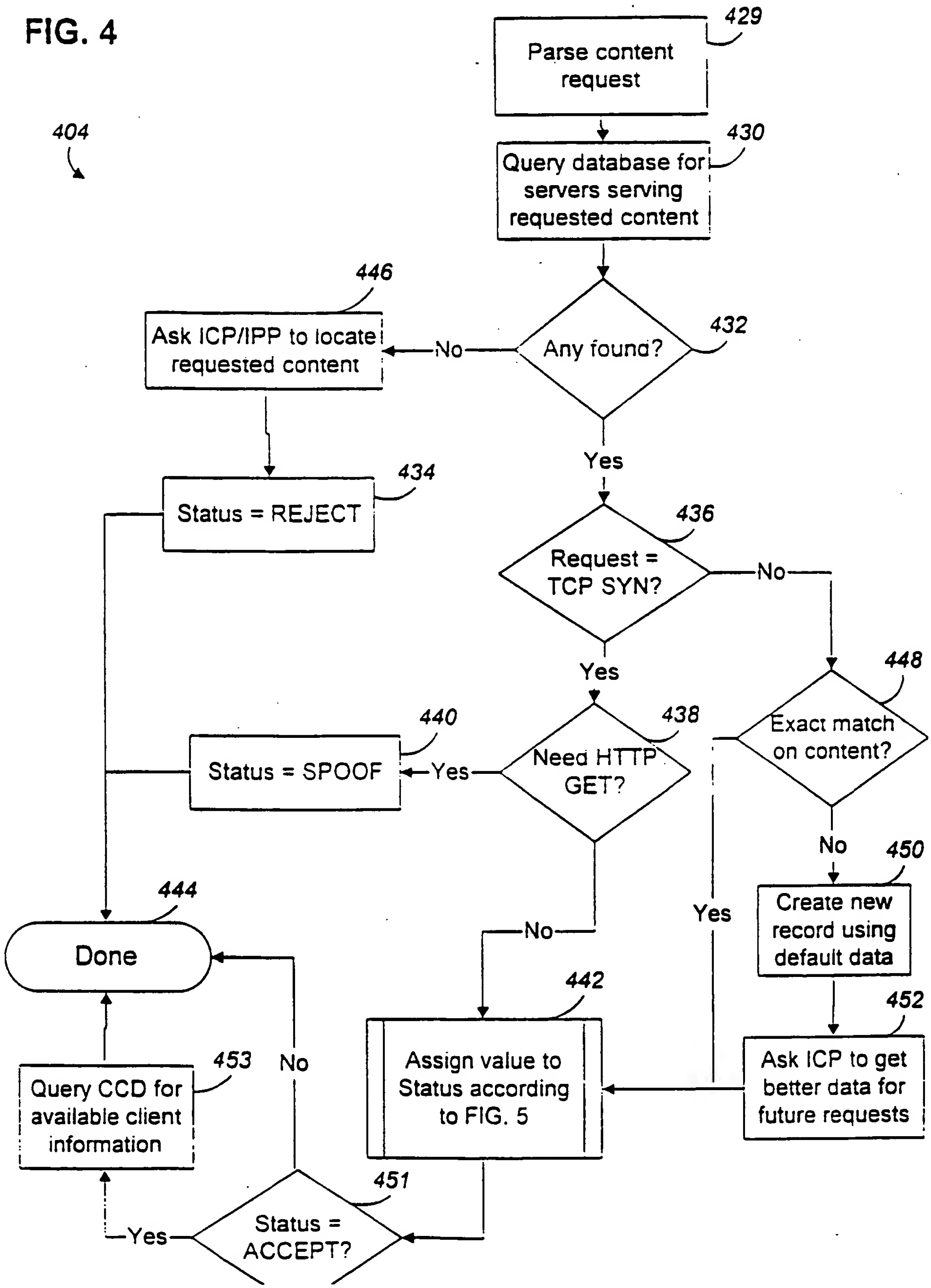

404
429
Parse content request
430
Query database for servers serving requested content
432
Any found?
No
446
Ask ICP/IPP to locate requested content
Yes
434
Status = REJECT
436
Request = TCP SYN?
No
Yes
448
Exact match on content?
438
Need HTTP GET?
Yes
440
Status = SPOOF
No
450
Create new record using default data
Yes
444
Done
No
442
Assign value to Status according to FIG. 5
452
Ask ICP to get better data for future requests
453
Query CCD for available client information
No
451
Status = ACCEPT?
Yes

FIG. 5

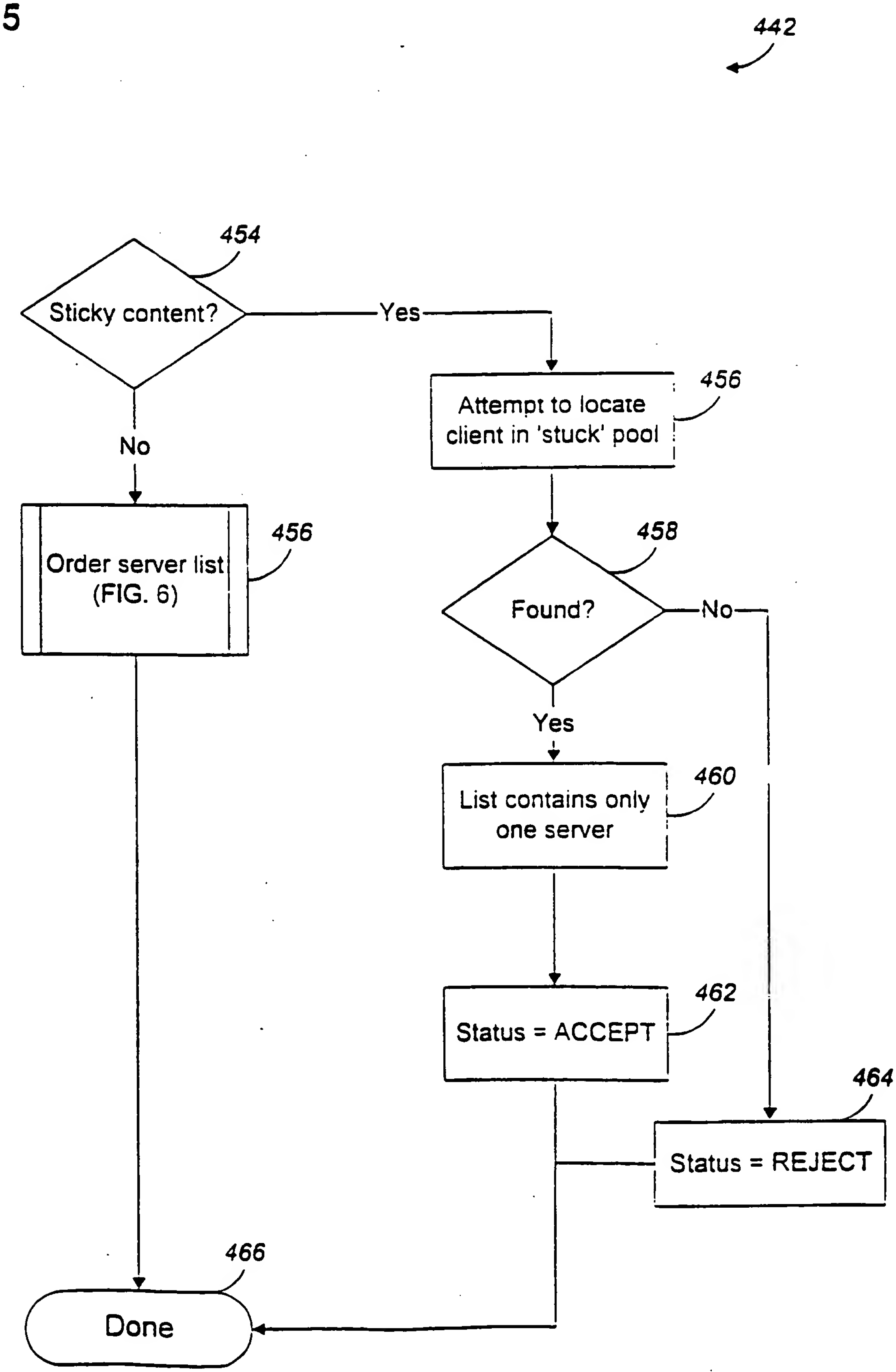

442
454
Sticky content?
Yes
No
Attempt to locate client in 'stuck' pool
456
Order server list (FIG. 6)
456
458
Found?
No
Yes
List contains only one server
460
Status = ACCEPT
462
464
Status = REJECT
466
Done

FIG. 6

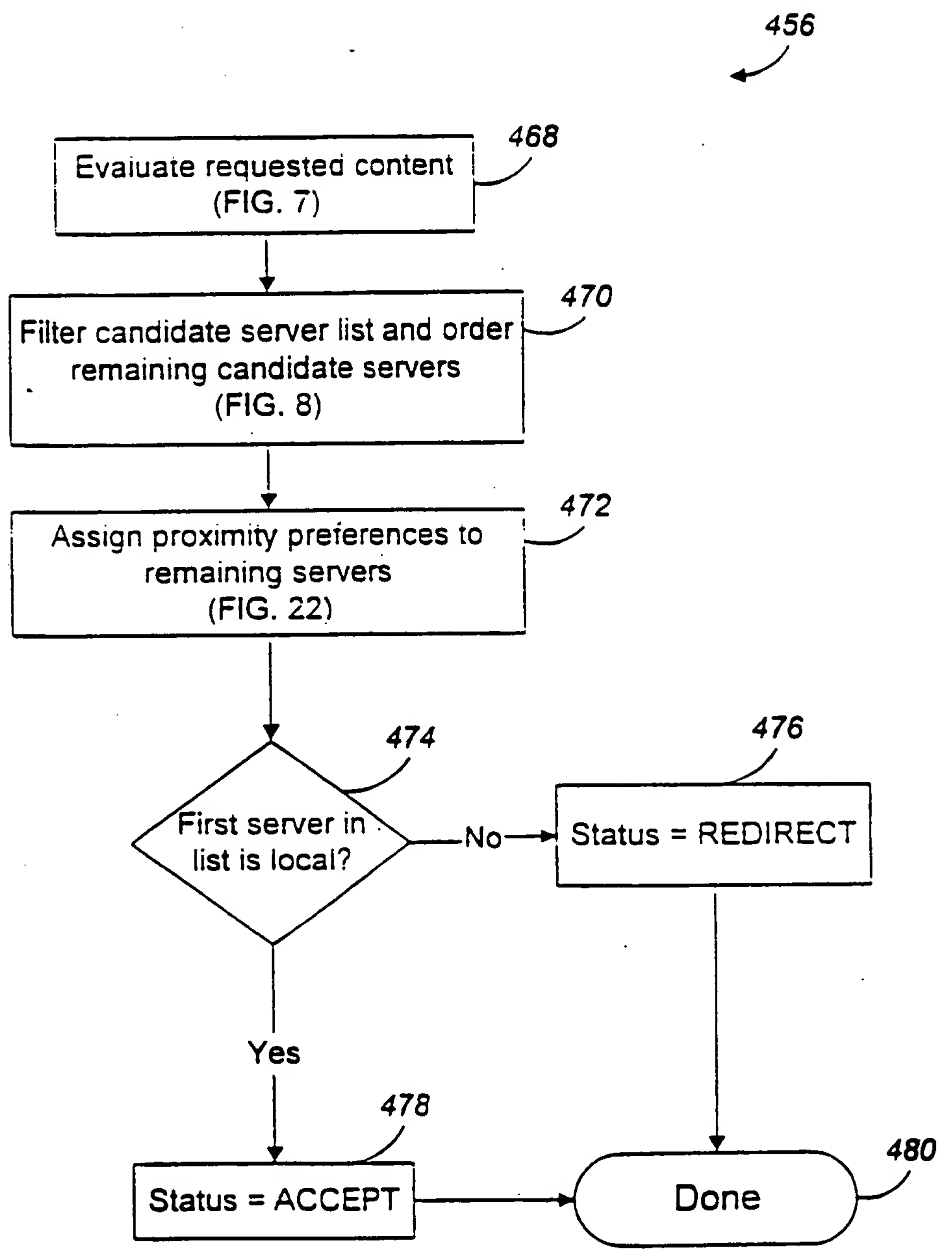

456
Evaluate requested content (FIG. 7)
468
Filter candidate server list and order remaining candidate servers (FIG. 8)
470
Assign proximity preferences to remaining servers (FIG. 22)
472
First server in list is local?
474
No
Status = REDIRECT
476
Yes
Status = ACCEPT
478
Done
480

FIG. 7

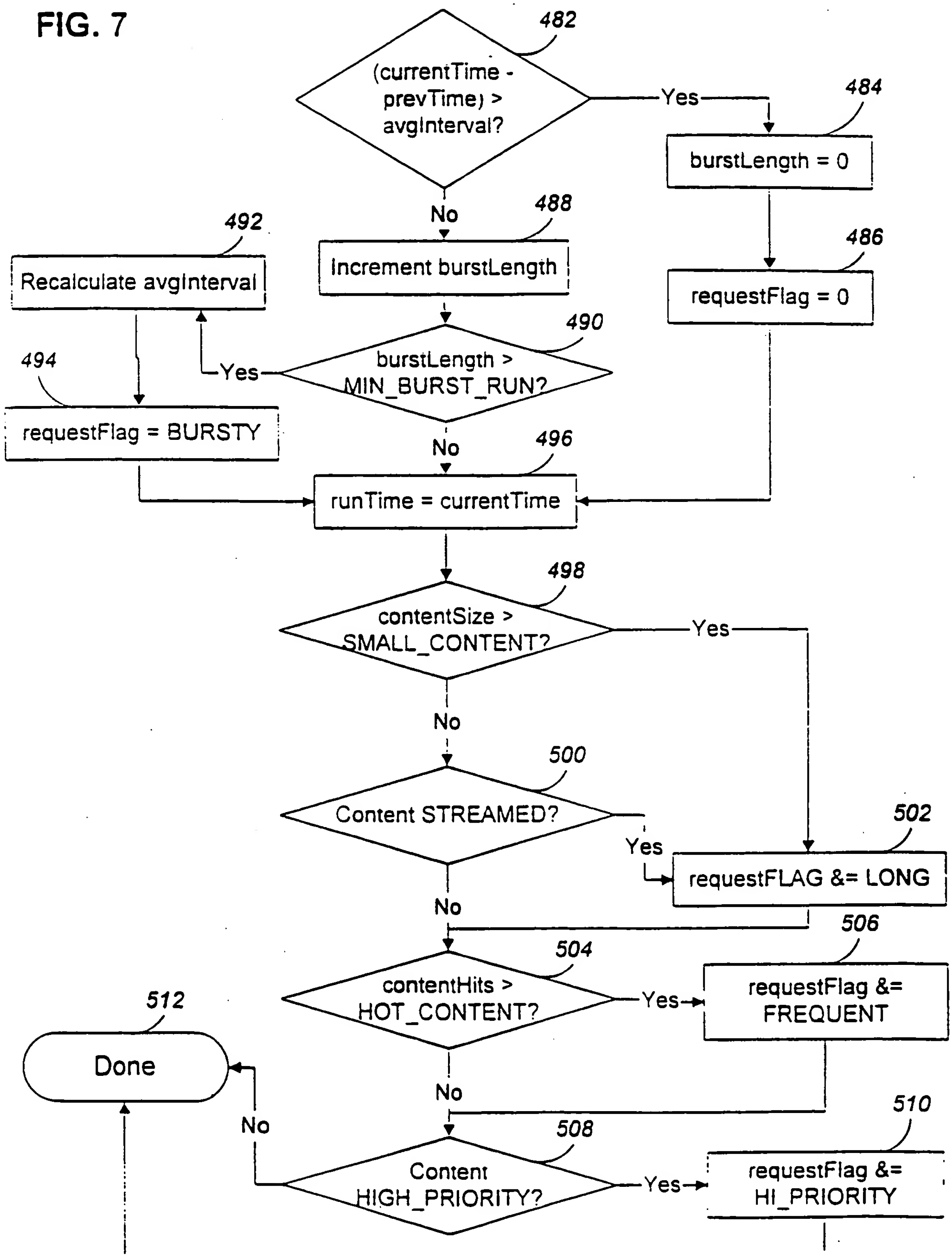

482
(currentTime - prevTime) > avgInterval?
Yes
484
burstLength = 0
486
requestFlag = 0
No
488
Increment burstLength
490
burstLength > MIN_BURST_RUN?
Yes
492
Recalculate avgInterval
494
requestFlag = BURSTY
No
496
runTime = currentTime
498
contentSize > SMALL_CONTENT?
Yes
No
500
Content STREAMED?
Yes
502
requestFLAG &= LONG
No
504
contentHits > HOT_CONTENT?
Yes
506
requestFlag &= FREQUENT
No
508
Content HIGH_PRIORITY?
Yes
510
requestFlag &= HI_PRIORITY
No
512
Done

FIG. 8

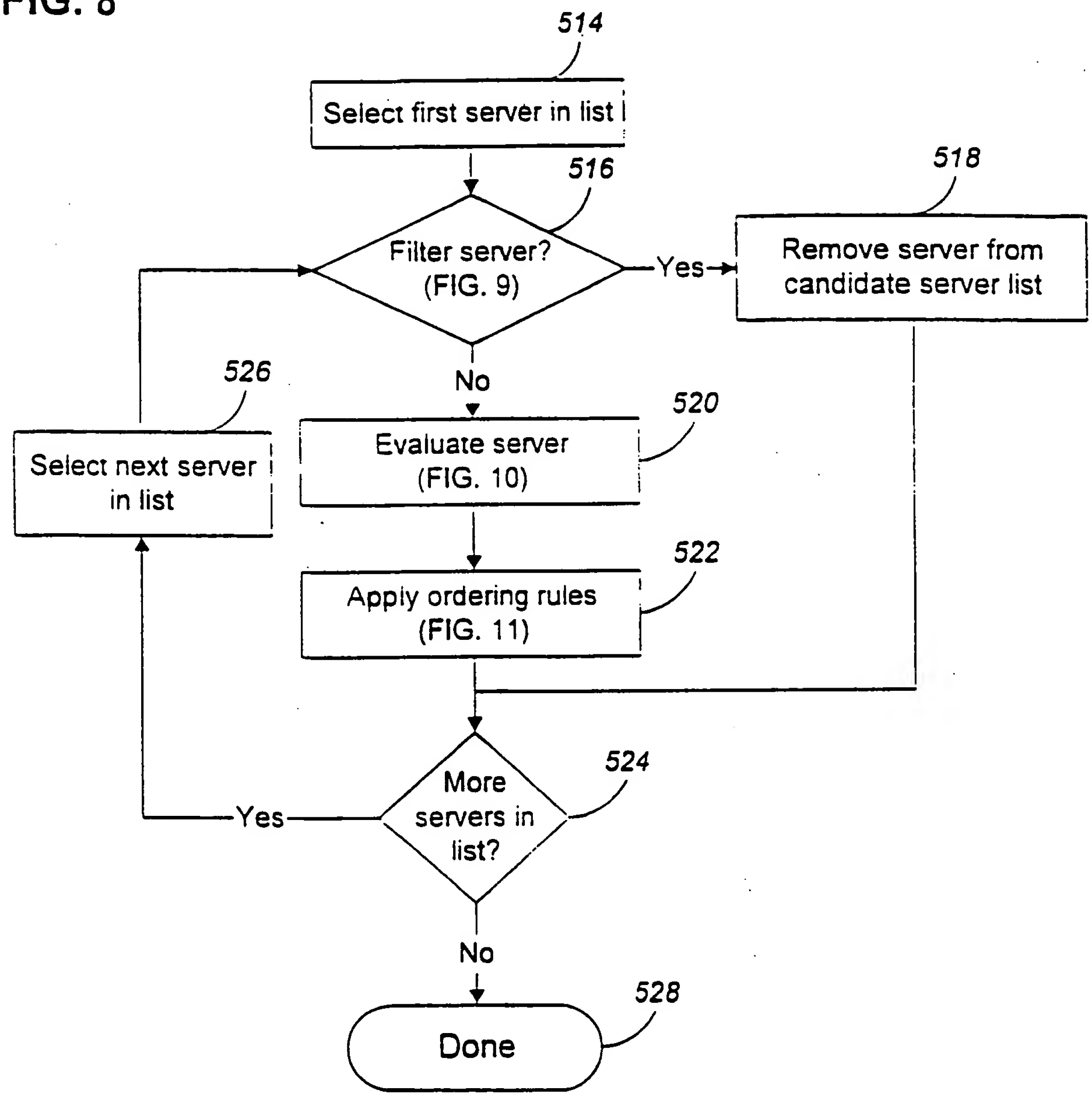

514
Select first server in list
516
Filter server?
(FIG. 9)
Yes
518
Remove server from candidate server list
No
526
Select next server in list
520
Evaluate server
(FIG. 10)
522
Apply ordering rules
(FIG. 11)
More servers in list?
524
Yes
No
528
Done

FIG. 9

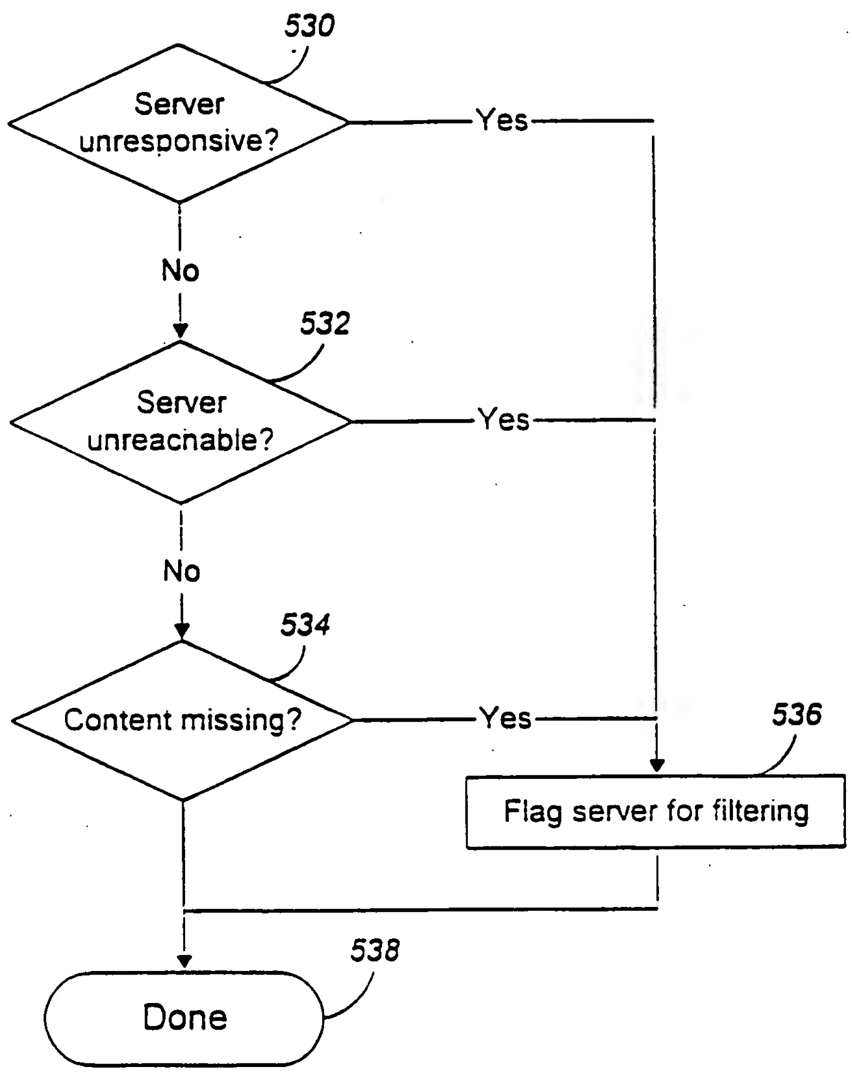

530
Server unresponsive?
Yes
No
532
Server unreachable?
Yes
No
534
Content missing?
Yes
536
Flag server for filtering
538
Done

FIG. 10

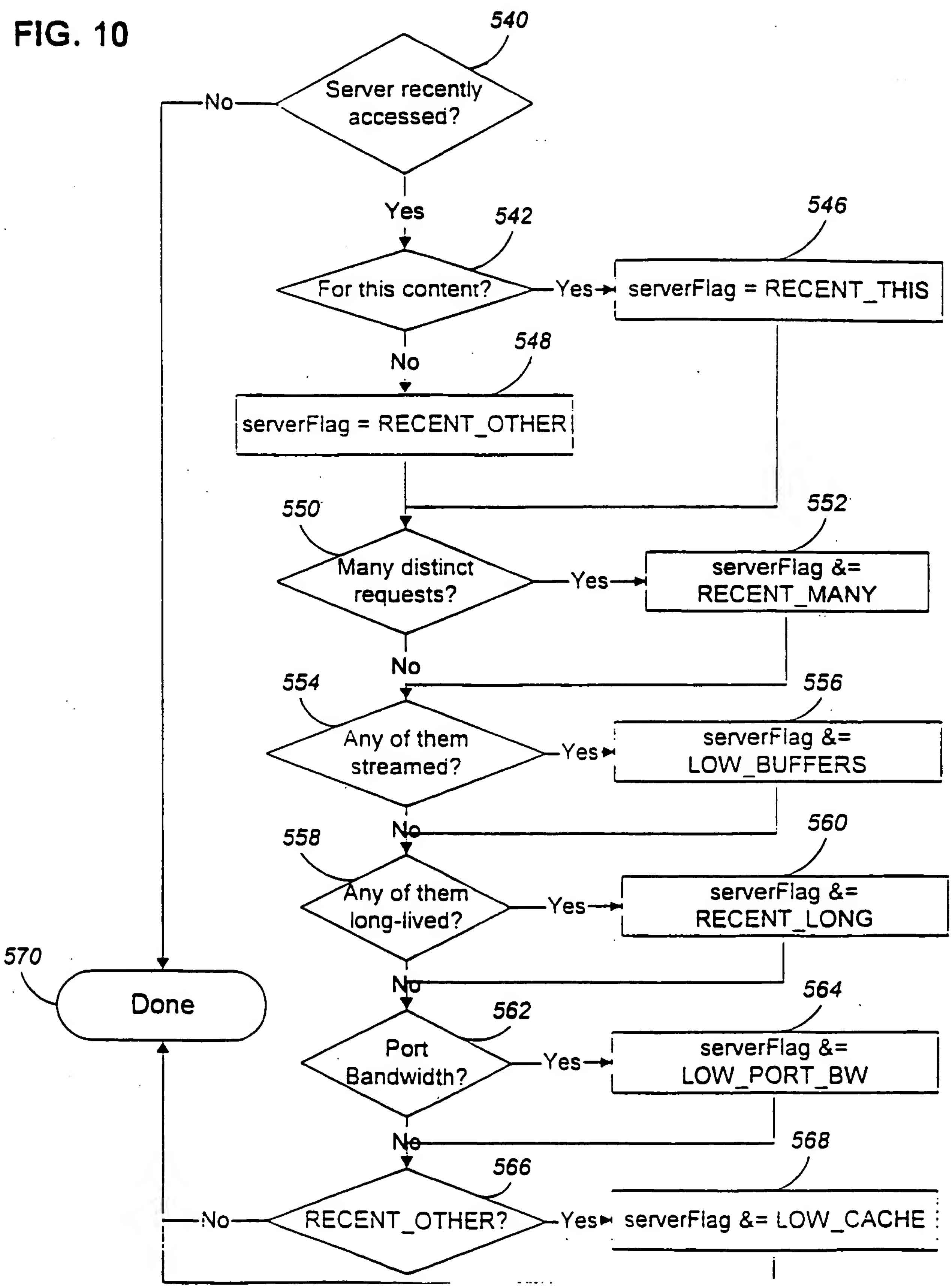

540
Server recently accessed?
No
Yes
542
For this content?
Yes
serverFlag = RECENT_THIS
546
No
548
serverFlag = RECENT_OTHER
550
Many distinct requests?
Yes
serverFlag &= RECENT_MANY
552
No
554
Any of them streamed?
Yes
serverFlag &= LOW_BUFFERS
556
No
558
Any of them long-lived?
Yes
serverFlag &= RECENT_LONG
560
No
570
Done
562
Port Bandwidth?
Yes
serverFlag &= LOW_PORT_BW
564
No
566
RECENT_OTHER?
No
Yes
serverFlag &= LOW_CACHE
568

FIG. 11

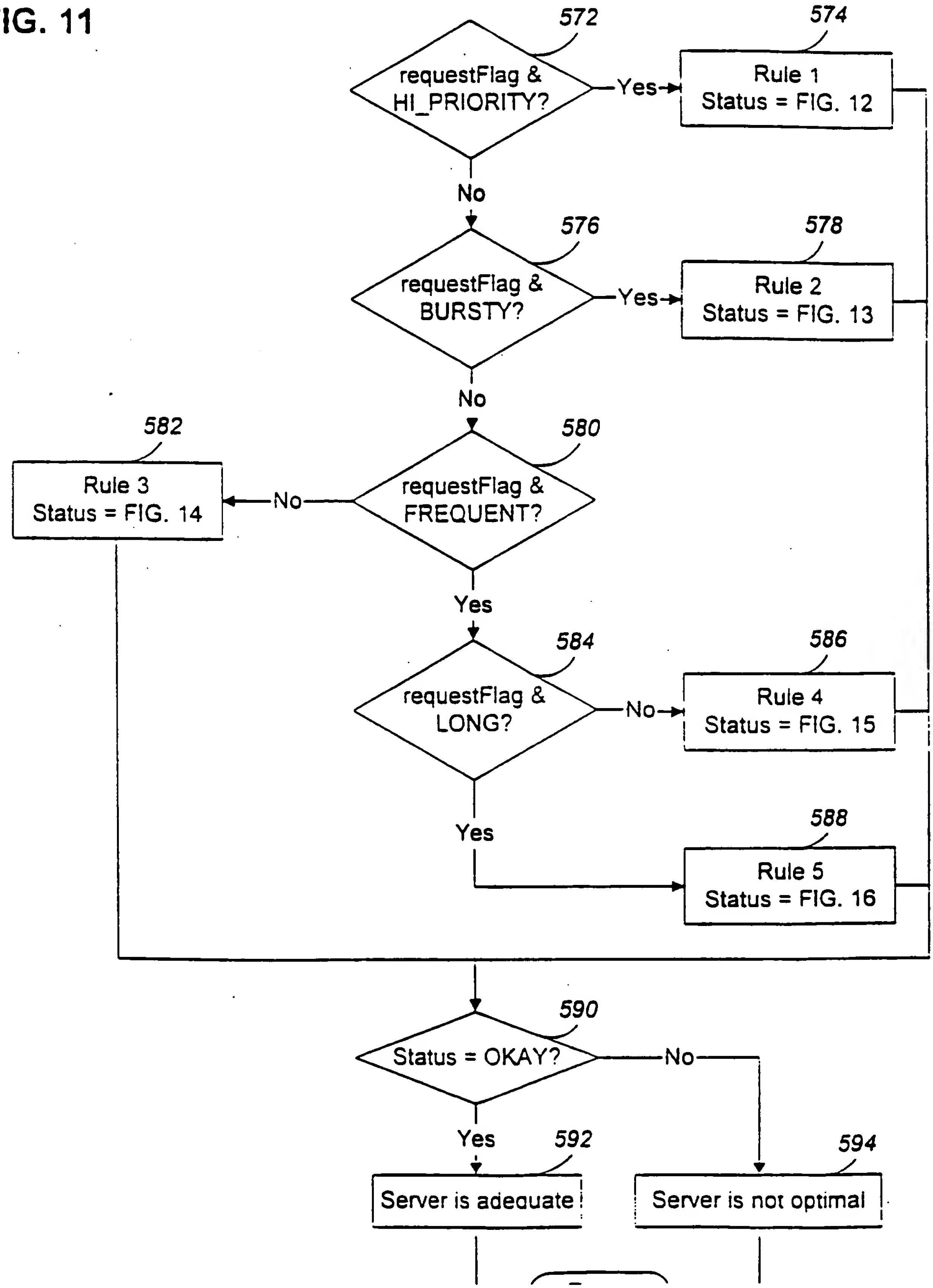

572
requestFlag &
HI_PRIORITY?
Yes
574
Rule 1
Status = FIG. 12
No
576
requestFlag &
BURSTY?
Yes
578
Rule 2
Status = FIG. 13
No
582
Rule 3
Status = FIG. 14
No
580
requestFlag &
FREQUENT?
Yes
584
requestFlag &
LONG?
No
586
Rule 4
Status = FIG. 15
Yes
588
Rule 5
Status = FIG. 16
590
Status = OKAY?
No
Yes
592
Server is adequate
594
Server is not optimal

FIG. 12

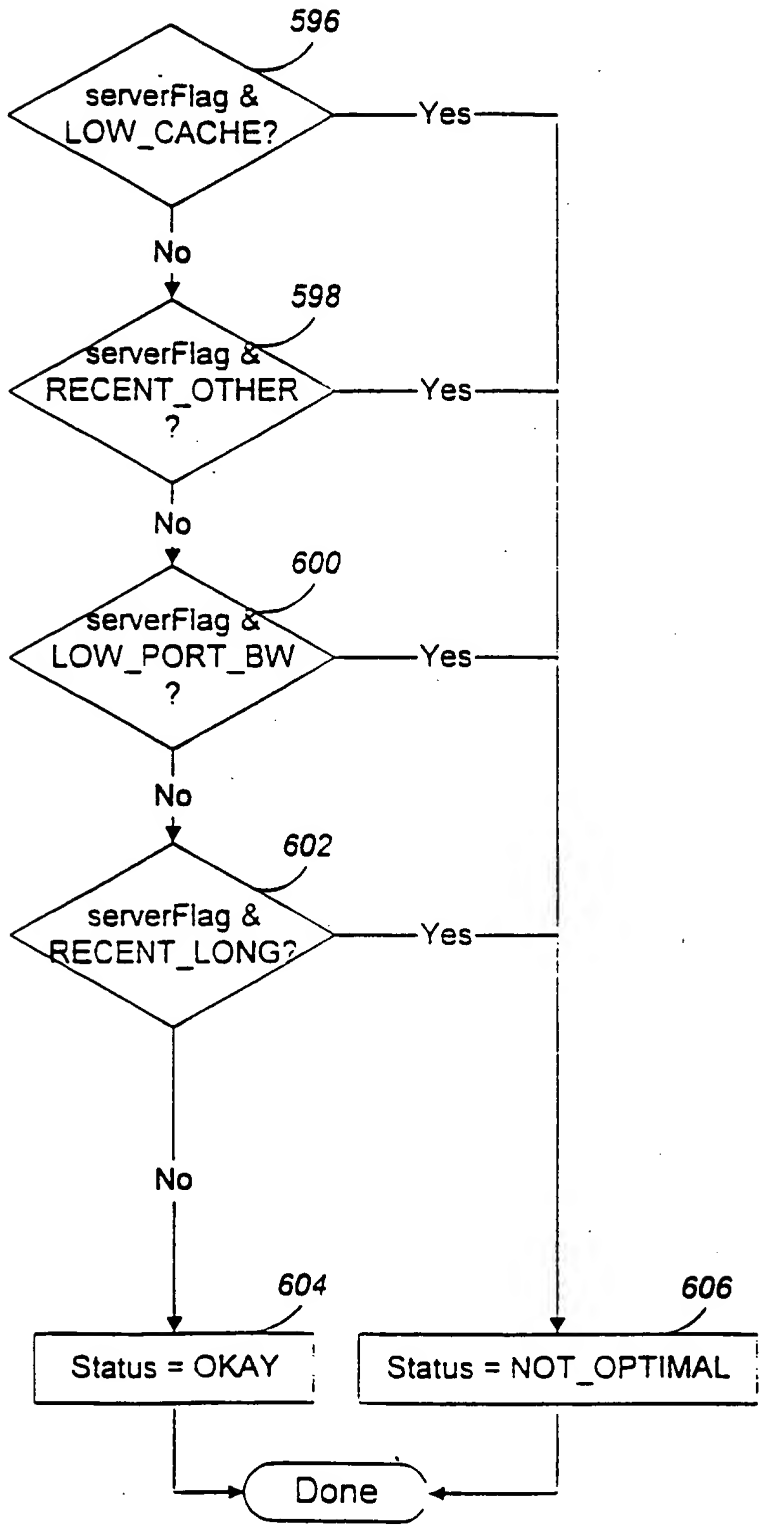

596
serverFlag &
LOW_CACHE?
Yes
No
598
serverFlag &
RECENT_OTHER
?
Yes
No
600
serverFlag &
LOW_PORT_BW
?
Yes
No
602
serverFlag &
RECENT_LONG?
Yes
No
604
Status = OKAY
606
Status = NOT_OPTIMAL
Done

FIG. 13

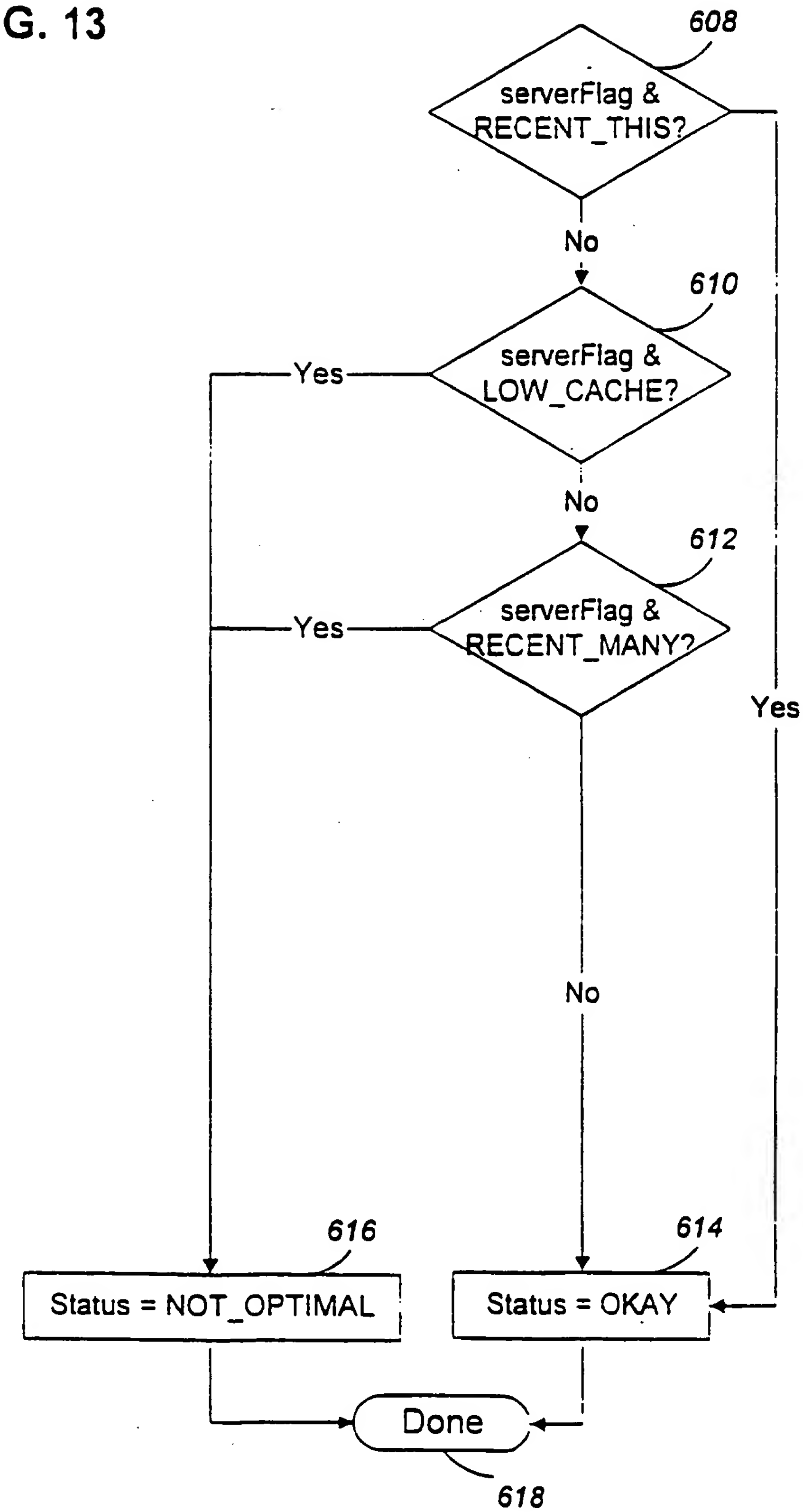

608
serverFlag & RECENT_THIS?
No
610
serverFlag & LOW_CACHE?
Yes
No
612
serverFlag & RECENT_MANY?
Yes
Yes
No
616
Status = NOT_OPTIMAL
614
Status = OKAY
Done
618

FIG. 14

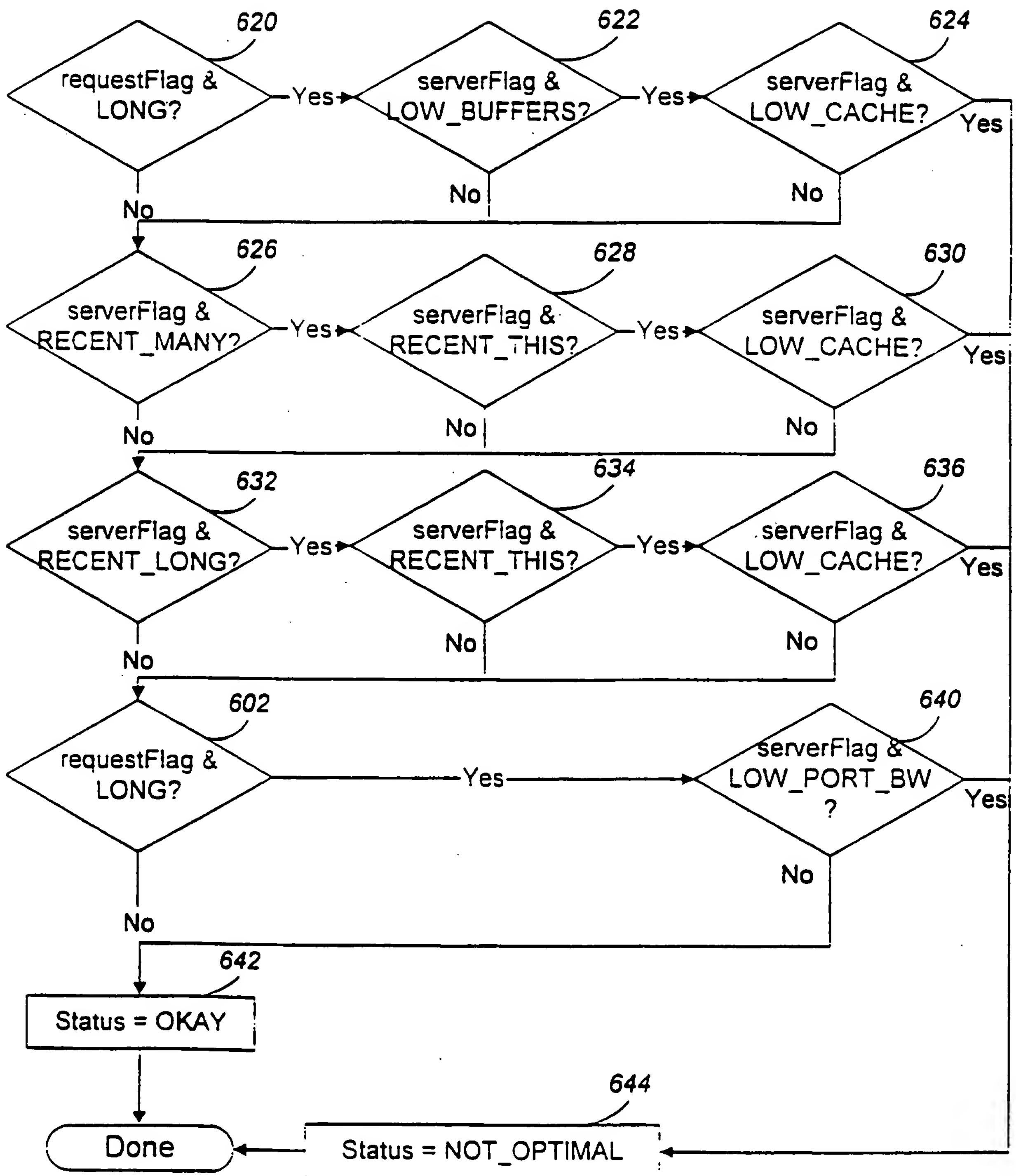

620
requestFlag & LONG?
Yes
No
622
serverFlag & LOW_BUFFERS?
Yes
No
624
serverFlag & LOW_CACHE?
Yes
No
626
serverFlag & RECENT_MANY?
Yes
No
628
serverFlag & RECENT_THIS?
Yes
No
630
serverFlag & LOW_CACHE?
Yes
No
632
serverFlag & RECENT_LONG?
Yes
No
634
serverFlag & RECENT_THIS?
Yes
No
636
serverFlag & LOW_CACHE?
Yes
No
602
requestFlag & LONG?
Yes
No
640
serverFlag & LOW_PORT_BW ?
Yes
No
642
Status = OKAY
Done
644
Status = NOT_OPTIMAL

FIG. 15

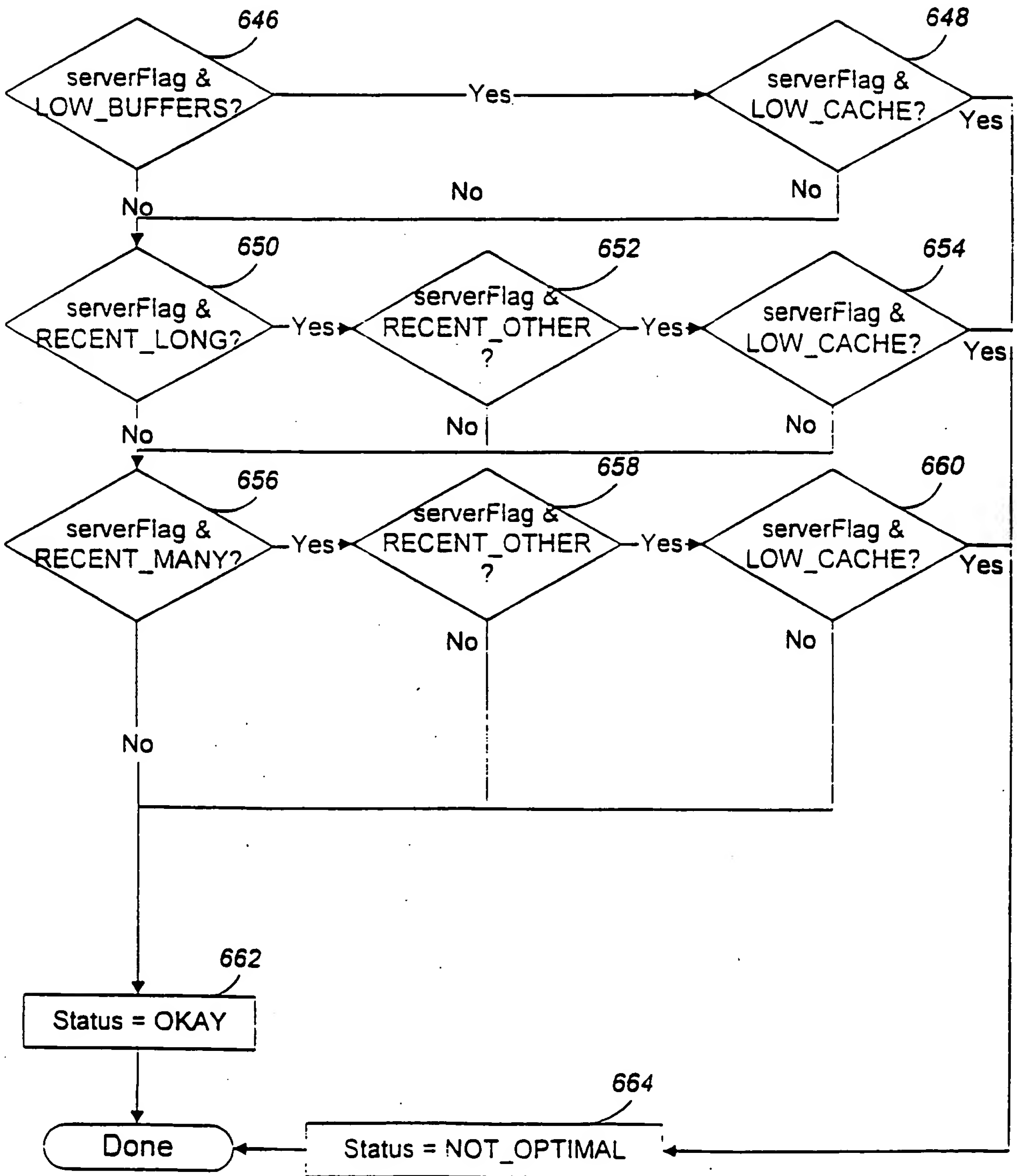

646
serverFlag & LOW_BUFFERS?
Yes
648
serverFlag & LOW_CACHE?
Yes
No
No
No
650
serverFlag & RECENT_LONG?
Yes
652
serverFlag & RECENT_OTHER ?
Yes
654
serverFlag & LOW_CACHE?
Yes
No
No
No
656
serverFlag & RECENT_MANY?
Yes
658
serverFlag & RECENT_OTHER ?
Yes
660
serverFlag & LOW_CACHE?
Yes
No
No
No
662
Status = OKAY
664
Done
Status = NOT_OPTIMAL

FIG. 16

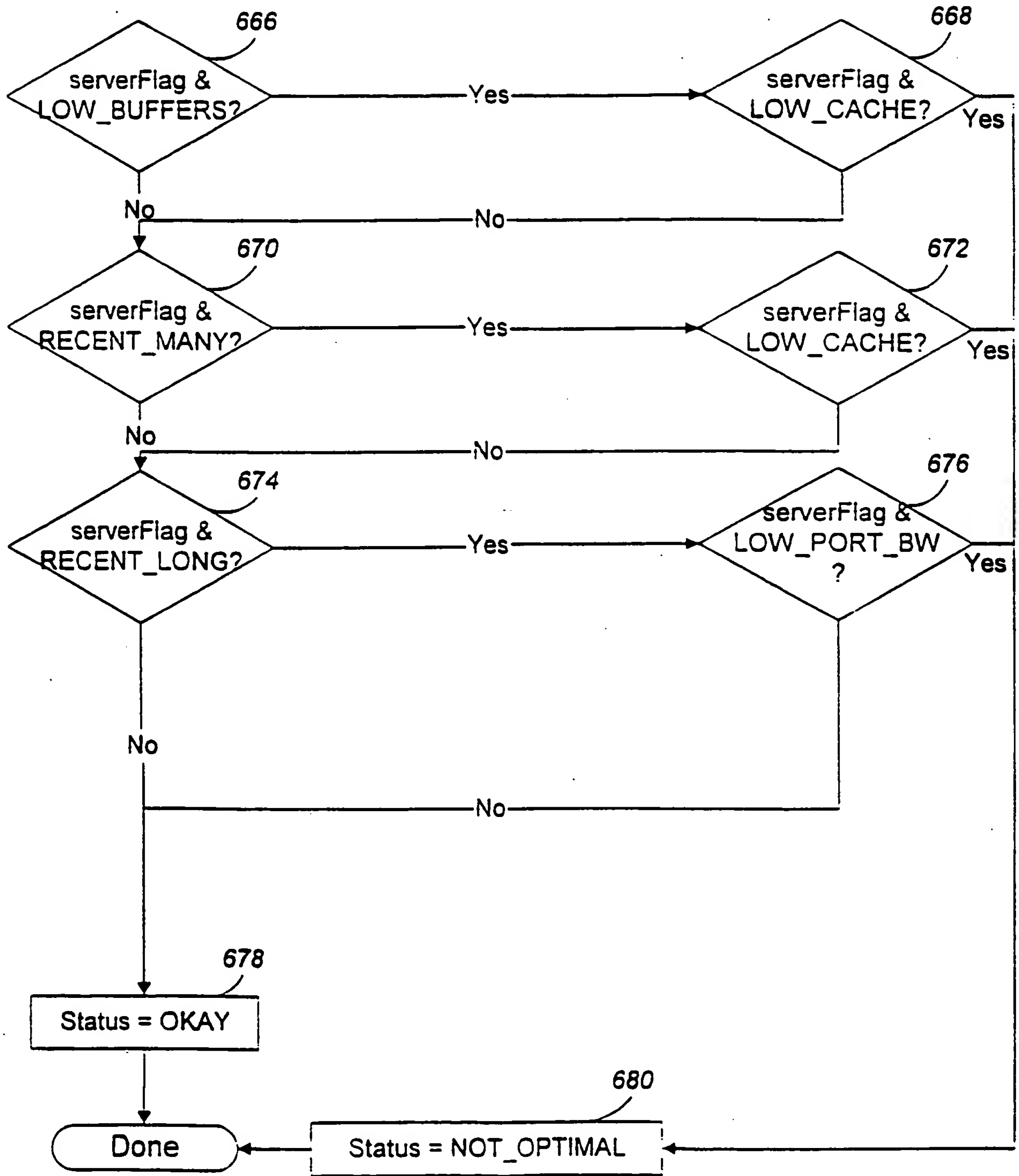

666
serverFlag & LOW_BUFFERS?
Yes
668
serverFlag & LOW_CACHE?
Yes
No
No
670
serverFlag & RECENT_MANY?
Yes
672
serverFlag & LOW_CACHE?
Yes
No
No
674
serverFlag & RECENT_LONG?
Yes
676
serverFlag & LOW_PORT_BW ?
Yes
No
No
678
Status = OKAY
680
Done
Status = NOT_OPTIMAL

FIG. 17

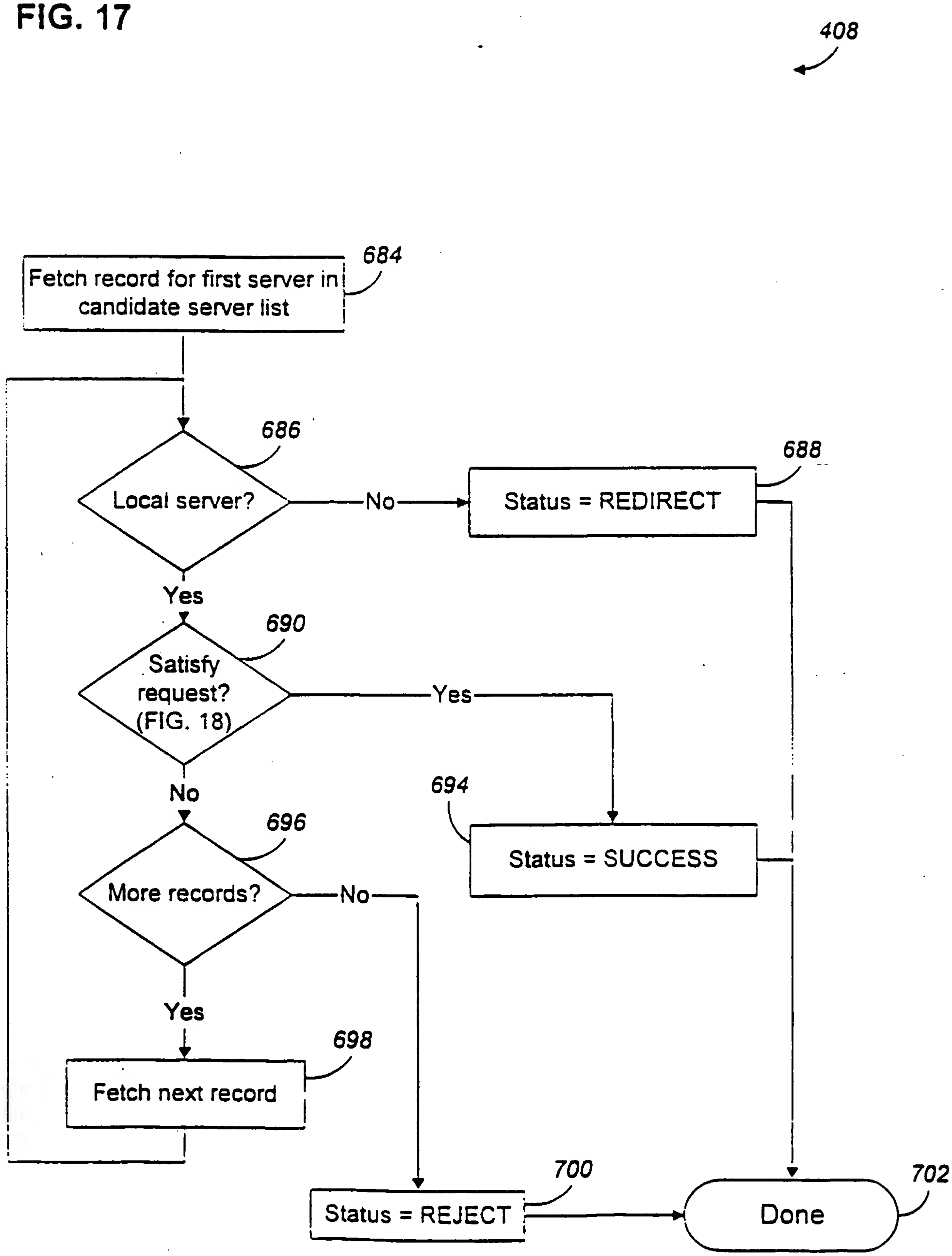

408
Fetch record for first server in candidate server list
684
Local server?
686
No
Status = REDIRECT
688
Yes
Satisfy request? (FIG. 18)
690
Yes
694
Status = SUCCESS
No
More records?
696
No
Yes
Fetch next record
698
Status = REJECT
700
Done
702

FIG. 18

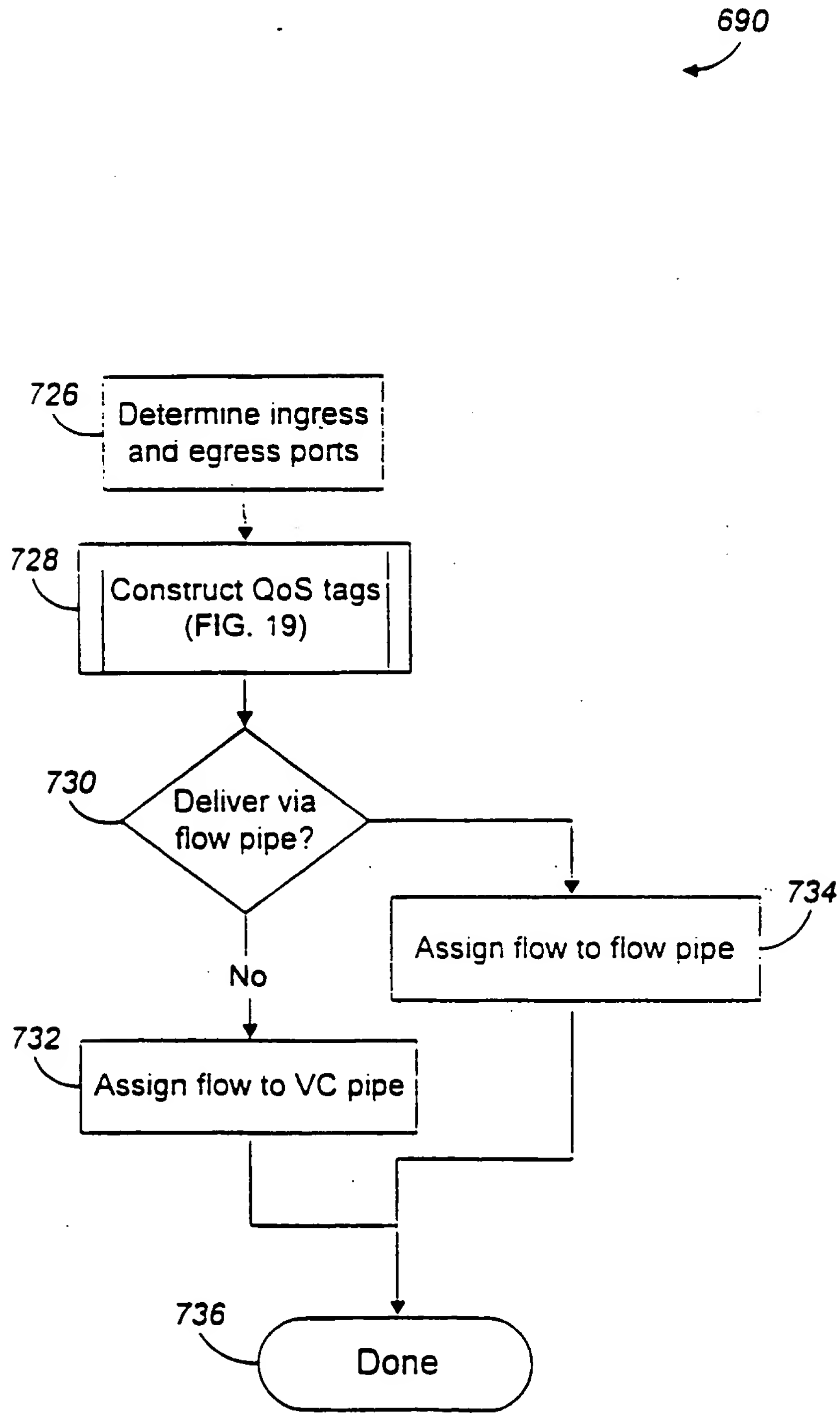

690
726
Determine ingress and egress ports
728
Construct QoS tags (FIG. 19)
730
Deliver via flow pipe?
No
734
Assign flow to flow pipe
732
Assign flow to VC pipe
736
Done

FIG. 19

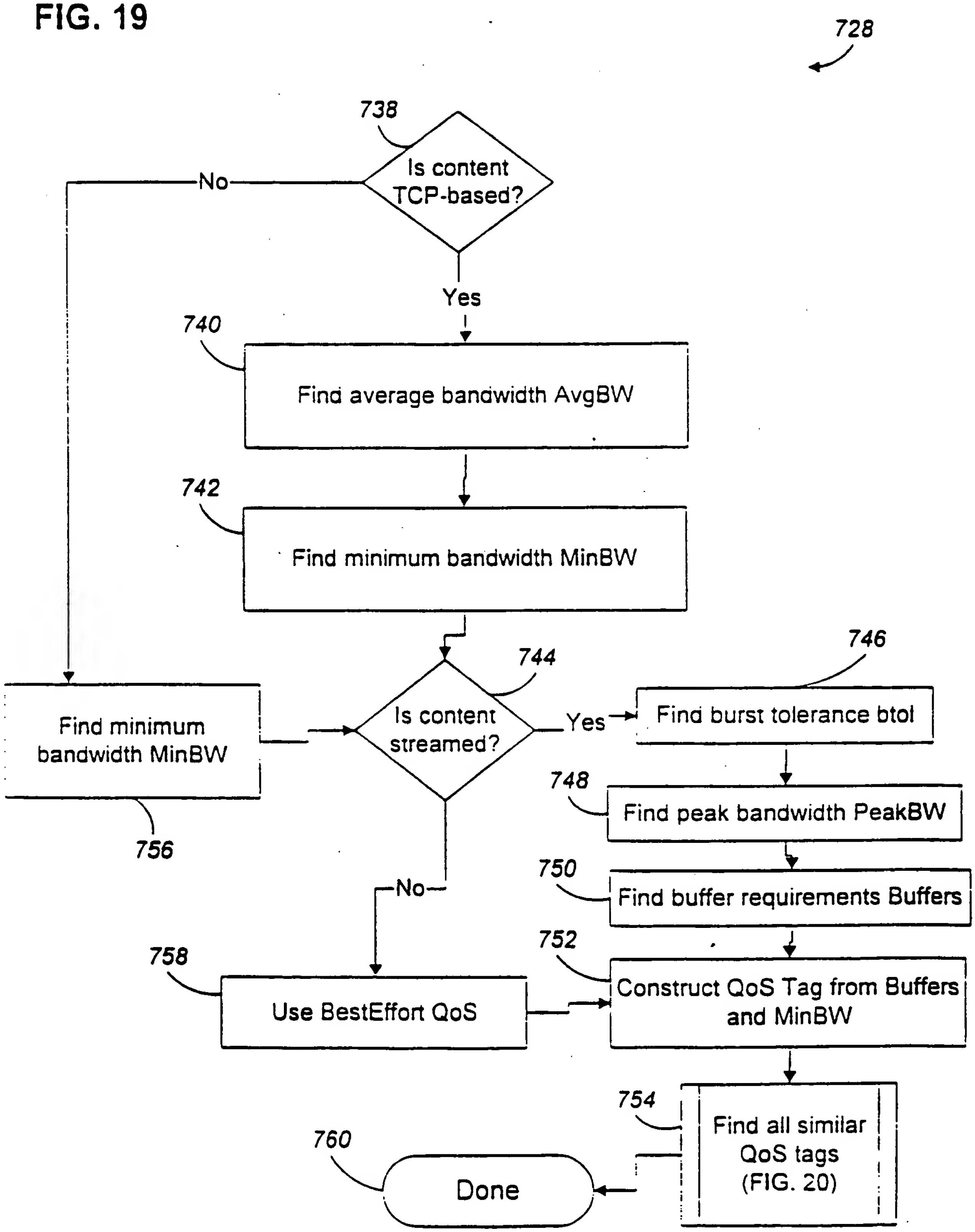

728
738
Is content TCP-based?
No
Yes
740
Find average bandwidth AvgBW
742
Find minimum bandwidth MinBW
744
Is content streamed?
Yes
746
Find burst tolerance btol
756
Find minimum bandwidth MinBW
748
Find peak bandwidth PeakBW
750
Find buffer requirements Buffers
No
758
Use BestEffort QoS
752
Construct QoS Tag from Buffers and MinBW
754
Find all similar QoS tags (FIG. 20)
760
Done

FIG. 20

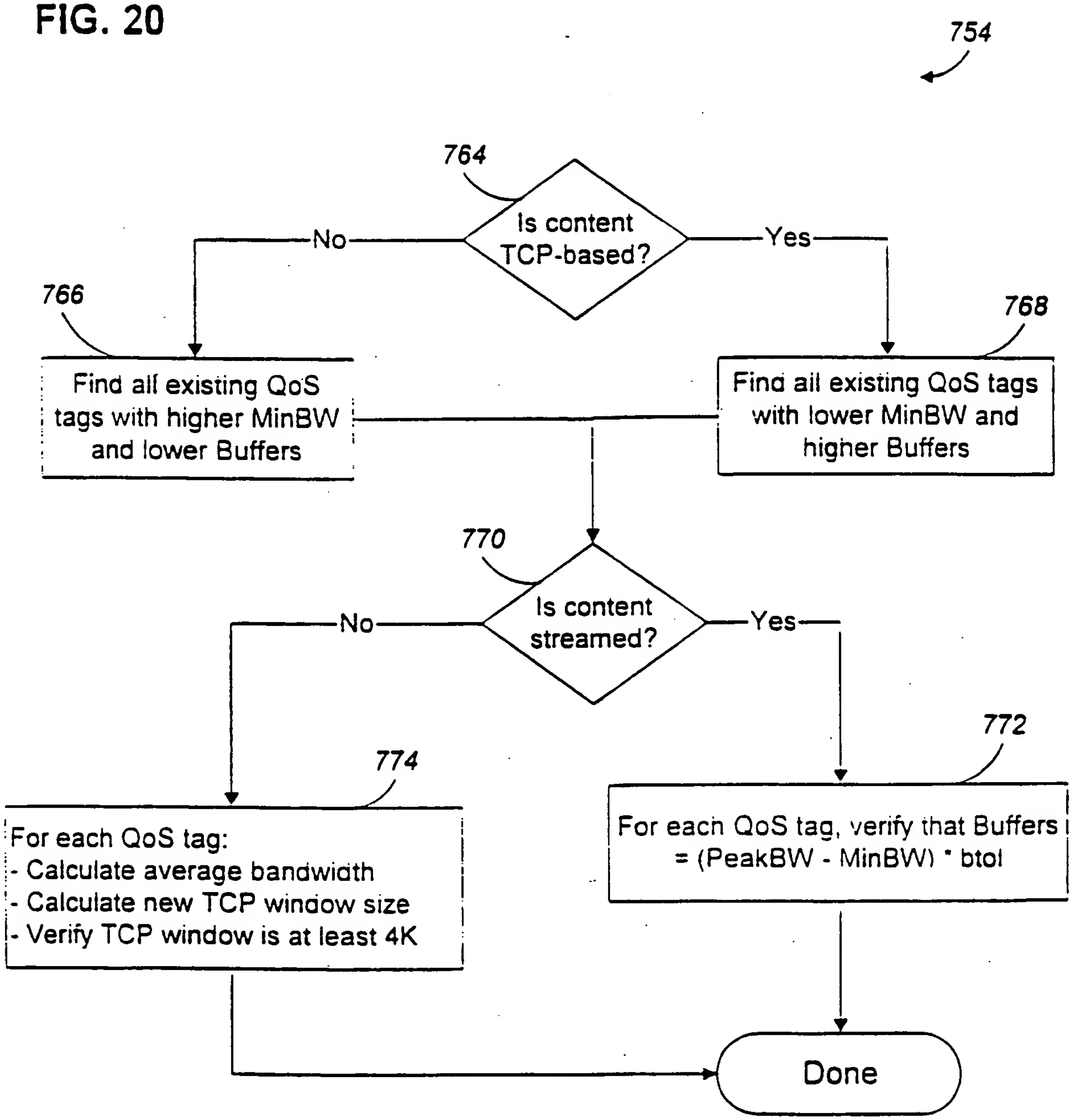
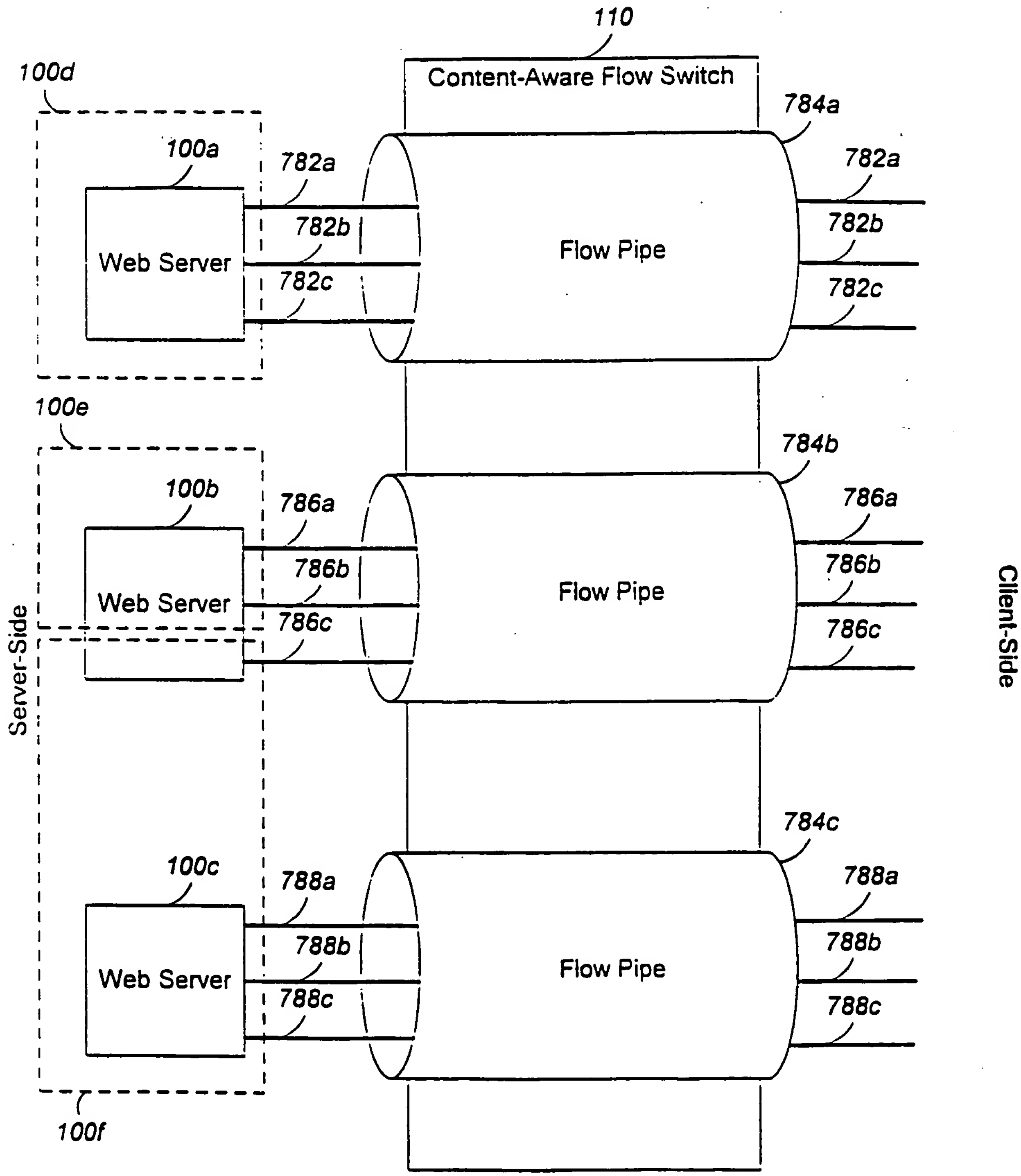
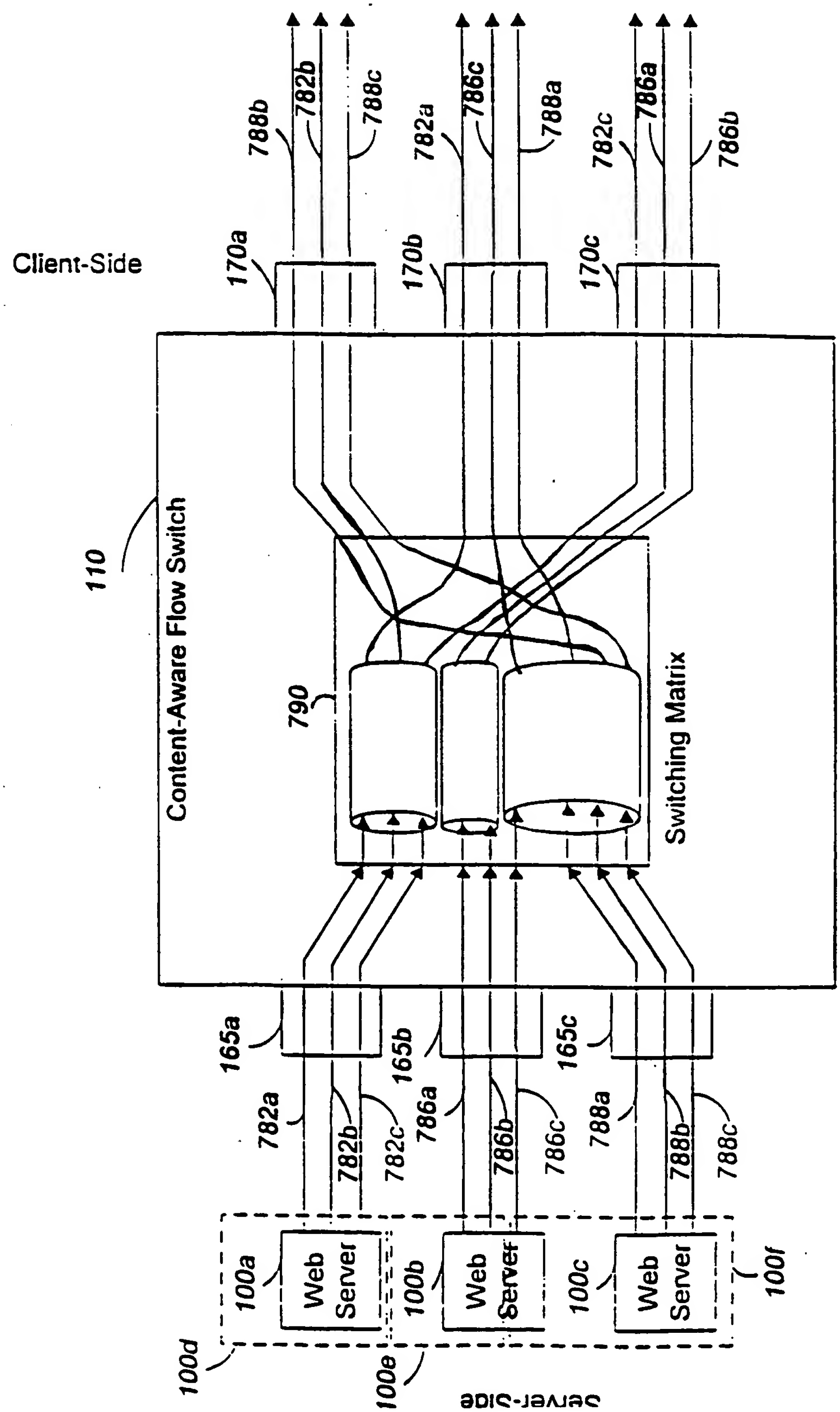

754
764
Is content TCP-based?
No
Yes
766
768
Find all existing QoS tags with higher MinBW and lower Buffers
Find all existing QoS tags with lower MinBW and higher Buffers
770
Is content streamed?
No
Yes
774
772
For each QoS tag:
- Calculate average bandwidth
- Calculate new TCP window size
- Verify TCP window is at least 4K
For each QoS tag, verify that Buffers = (PeakBW - MinBW) * btol
Done

FIG. 21a


110
Content-Aware Flow Switch
100d
100a
Web Server
782a
782b
782c
784a
Flow Pipe
782a
782b
782c
100e
100b
Web Server
786a
786b
786c
784b
Flow Pipe
786a
786b
786c
Server-Side
Client-Side
100c
Web Server
788a
788b
788c
784c
Flow Pipe
788a
788b
788c
100f



Client-Side
170a
170b
170c
788b
782b
788c
782a
786c
788a
782c
786a
786b
110
Content-Aware Flow Switch
790
Switching Matrix
165a
165b
165c
782a
782b
782c
786a
786b
786c
788a
788b
788c
100a
100b
100c
Web Server
Web Server
Web Server
100d
100e
100f
Server-Side


FIG. 21b

FIG. 22

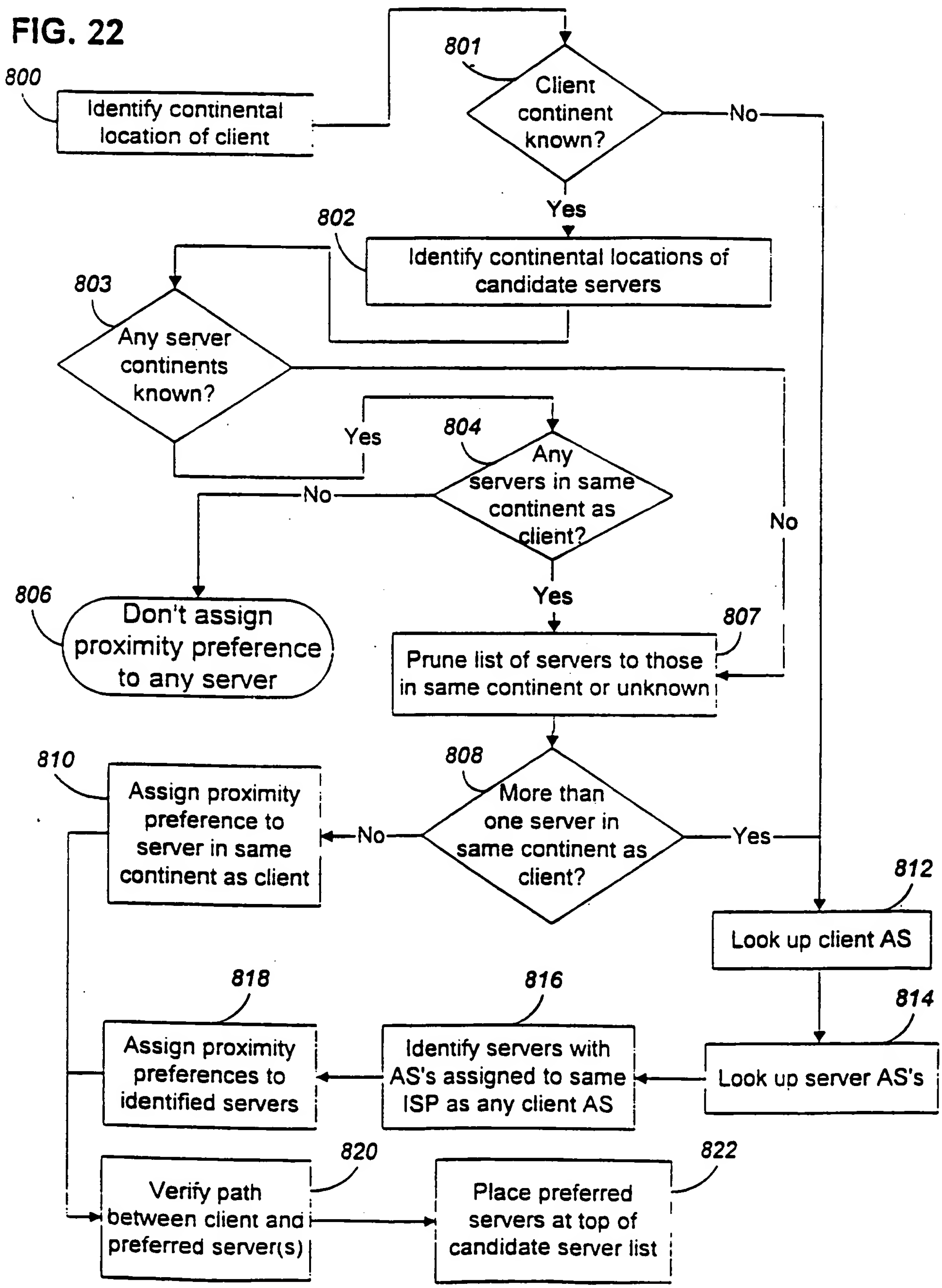
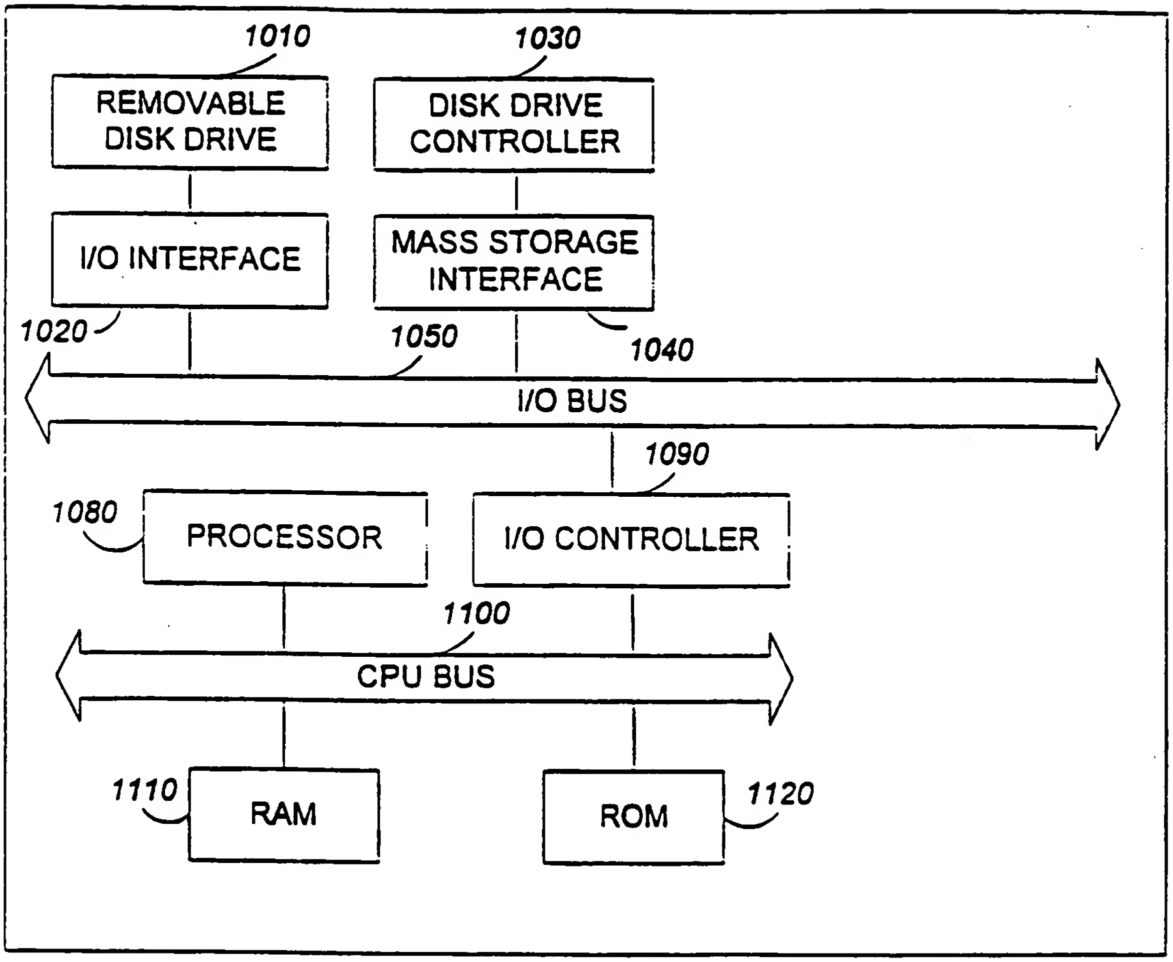

800
Identify continental location of client
801
Client continent known?
No
Yes
802
Identify continental locations of candidate servers
803
Any server continents known?
Yes
804
Any servers in same continent as client?
No
No
806
Don't assign proximity preference to any server
Yes
807
Prune list of servers to those in same continent or unknown
808
More than one server in same continent as client?
810
Assign proximity preference to server in same continent as client
No
Yes
812
Look up client AS
814
Look up server AS's
816
Identify servers with AS's assigned to same ISP as any client AS
818
Assign proximity preferences to identified servers
820
Verify path between client and preferred server(s)
822
Place preferred servers at top of candidate server list

FIG. 23


1010
REMOVABLE DISK DRIVE
1030
DISK DRIVE CONTROLLER
I/O INTERFACE
MASS STORAGE INTERFACE
1020
1050
1040
I/O BUS
1090
1080
PROCESSOR
I/O CONTROLLER
1100
CPU BUS
1110
RAM
ROM
1120

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/11912

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC(6) :G06F 13/00
US CL :395/200.33, 200.56, 200.59, 200.53, 200.54
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 395/200.33, 200.56, 200.59, 200.53, 200.54

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 5,341,477 A (PITKIN et al) 23 August 1994, col. 2, lines 35-68, col. 3, lines 1-60, col. 4, line 15 to col. 11, line 45. | 1, 5-10, 12-33, 37, 39-44, 47-49 |
| Y | US 5,459,837 A (CACCAVALE) 17 October 1995, col. 1-2, col. 3, line 55 to col.9, line 63. | 1, 5-10, 12-33, 37, 39-44, 47-49 |
| A | US 5,475,819 A (MILLER et al) 12 December 1995, see the whole reference. | 1-37,39-49 |
| A | US 5,230,065 A (CURLEY et al) 20 July 1993, see the whole reference. | 1-37,39-49 |
| A | US 5,031,089 A (LIU et al) 09 July 1991, see the whole reference. | 1-37,39-49 |

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 10 SEPTEMBER 1998 | 18 NOV 1998 |

| Name and mailing address of the ISA/US | Authorized officer |
|---|---|
| Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231 | ZARNI MAUNG |

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/11912

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5,249,290 A (HEIZER) 28 September 1993, see the whole reference. | 1-37, 39-49 |
| Y | US 5,574,861 A (LORVIG et al) 12 November 1996, col. 7, line 11 to col. 9, line 65. | 38 |
| Y | US 5,475,685 A (GARRIS et al) 12 December 1995, col.2, lines 20-34, col. 4, line 59 to col. 5, line 54. | 38 |
| A | US 5,701,465 A (BAUGHER et al) 23 December 1997, see the whole reference. | 38 |
| A | US 5,673,393 A (MARSHALL et al) 30 September 1997, see the whole reference. | 38 |

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/11912

**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest** ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claims 1-37 and 39-49 are directed to a method and system for directing a flow between a client and a best-fit server.

Group II, claim 38 is directed to a method for allocating bandwidth of a data switching device.

The inventions listed as Groups I and II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Group I, claims 1-37 and 39-49 contains the special technical features for directing a flow between a client and a best-fit server.

Group II, claim 38 contains the special technical features for allocating bandwidth of a data switching device.

| | Description | | | | Date→ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AH Meters → | | | | | | |
| | Self - Test Faults | Thr | Fault Cd | Loc | 1 | 2 | 3 | 4 | 5 | Loc | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144.J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146.J147 H018 | 004L | | | | | | C04L | |
| | XER failed self-test | 2 | J148.J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023.J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155.J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | H.V. Faults | | | | | | | | | | |
| | | | | | | | | | | 009L | A |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 010L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 011L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 012L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 013L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | #NAME? | 014L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | | 015L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 016L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 017L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | | |
| | System Errors | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | 1 | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | Timing Faults | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | Document Handler Faults | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190.A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222.A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 7 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201.A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016.A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

| | Description | Thr | Fault Cd | Loc | 1 | 2 | 3 | 4 | 5 | Loc | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Date→ | | | | | | | | |
| | | | AH Meters → | | | | | | | | |
| | **Self - Test Faults** | | | | | | | | | | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144.J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146.J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148.J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023.J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155.J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | / | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190.A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222,A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 2 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201,A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016.A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

| | Description | Thr | Fault Cd | Loc | 1 | 2 | 3 | 4 | 5 | Loc | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Date→ | | | | | | | | |
| | | | AH Meters → | | | | | | | | |
| | **Self - Test Faults** | **Thr** | **Fault Cd** | **Loc** | **1** | **2** | **3** | **4** | **5** | **Loc** | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144 J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146 J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148 J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023 J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155 J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | 1 | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190 A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222 A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 7 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201 A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016 A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

| | Description | Thr | Fault Cd | Loc | 1 | 2 | 3 | 4 | 5 | Loc | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Date→ | | | | | | | |
| | | | | AH Meters → | | | | | | | |
| | **Self - Test Faults** | | | | | | | | | | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144,J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146,J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148,J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023,J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155,J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | / | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190,A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222,A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 2 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201,A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016,A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

ADVUA

| | Description | | Date→ | | 1 | 2 | 3 | 4 | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AH Meters → | | | | | | | | |
| | **Self - Test Faults** | **Thr** | **Fault Cd** | **Loc** | **1** | **2** | **3** | **4** | **5** | **Loc** | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144.J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146.J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148.J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023.J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155.J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | / | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190.A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222.A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 7 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201.A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | P |
| | Doc handler shutter fault | 5 | A016.A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

| | Description | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Date→ | | | | | | | | |
| | | | AH Meters → | | | | | | | | |
| | **Self - Test Faults** | **Thr** | **Fault Cd** | **Loc** | **1** | **2** | **3** | **4** | **5** | **Loc** | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144.J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146.J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148.J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023.J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155.J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | / | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190.A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222.A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 2 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201.A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016.A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

| | Description | Thr | Fault Cd | Loc | 1 | 2 | 3 | 4 | 5 | Loc | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Date→ | | | | | | | | |
| | | | AH Meters → | | | | | | | | |
| | **Self - Test Faults** | **Thr** | **Fault Cd** | **Loc** | **1** | **2** | **3** | **4** | **5** | **Loc** | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144.J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146.J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148.J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023.J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155.J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | 1 | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190.A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222.A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 2 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201.A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016.A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

5680/5892 [illegible]

| | Description | | | | 1 | 2 | 3 | 4 | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Date→ | | | | | | | | |
| | | | AH Meters → | | | | | | | | |
| | **Self - Test Faults** | **Thr** | **Fault Cd** | **Loc** | **1** | **2** | **3** | **4** | **5** | **Loc** | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144,J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146,J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148,J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023,J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155,J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | / | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190,A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222,A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 2 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201,A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | P |
| | Doc handler shutter fault | 5 | A016,A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

5680/5892 DC 20 Error Log

| | Description | | | Date→ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | AH Meters → | | | | | | |

| | Self - Test Faults | Thr | Fault Cd | Loc | 1 | 2 | 3 | 4 | 5 | Loc | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144,J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146,J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148,J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023,J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155,J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | / | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | H029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190,A225 A208 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222,A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 2 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201,A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016,A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistlip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

5

5680/5892 DC 20 Error Log

| | Description | Thr | Fault Cd | Loc | 1 | 2 | 3 | 4 | 5 | Loc | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Date→ | | | | | | | | |
| | | | AH Meters → | | | | | | | | |
| | **Self - Test Faults** | **Thr** | **Fault Cd** | **Loc** | **1** | **2** | **3** | **4** | **5** | **Loc** | |
| | CDM failed self-test | 2 | H015 | 000L | | | | | | 000L | |
| | PHR failed self-test | 2 | J144.J145 H017 | 003L | | | | | | 003L | |
| | MIR failed self-test | 2 | J146.J147 H018 | 004L | | | | | | 004L | |
| | XER failed self-test | 2 | J148.J149 H019 | 005L | | | | | | 005L | |
| | ISR failed self-test | 2 | J023.J188 J189 | 006L | | | | | | 006L | |
| | FOR failed self-test | 2 | J155.J156 L020 | 007L | | | | | | 007L | |
| | Shared line failure | 2 | H014 | 008L | | | | | | 008L | |
| | **H.V. Faults** | | | | | | | | | | |
| A | AC voltage fault | 5 | F059 | 009L | | | | | | 009L | A |
| A | Charge #2 voltage fault | 5 | F060 | 010L | | | | | | 010L | A |
| A | Transfer current fault | 5 | J061 | 011L | | | | | | 011L | A |
| A | Preclean current fault | 5 | F062 | 012L | | | | | | 012L | A |
| A | Developer bias fault | 5 | F063 | 013L | | | | | | 013L | A |
| A | Toner bias fault | 5 | F064 | 014L | | | | | #NAME? | 014L | A |
| A | Cleaner bias fault | 5 | F065 | 015L | | | | | | 015L | A |
| A | Waste roll bias fault | 5 | J067 | 016L | | | | | | 016L | A |
| A | Arc detector fault | 5 | F068 | 017L | | | | | | 017L | A |
| | **System Errors** | | | | | | | | | | |
| | System error (CDM) | 5 | N/A | 018L | | | | | | 018L | |
| | System error (ISR) | 5 | N/A | 019L | | / | | | | 019L | |
| | System error (PHR) | 5 | N/A | 020L | | | | | | 020L | |
| | System error (MIR) | 5 | N/A | 021L | | | | | | 021L | |
| | System error (XER) | 5 | N/A | 022L | | | | | | 022L | |
| | System error (FOR) | 5 | N/A | 023L | | | | | | 023L | |
| | Power loss in print | 3 | N/A | 024L | | | | | | 024L | |
| | **Timing Faults** | | | | | | | | | | |
| | Timing reset faults | 2 | J028 | 026L | | | | | | 026L | |
| | Too few belt holes | 2 | J029 | 027L | | | | | | 027L | |
| | Too many belt holes | 2 | F137 | 028L | | | | | | 028L | |
| | CDM lost machine clocks | 5 | F004 | 029L | | | | | | 029L | |
| | MIR lost machine clocks | 5 | F005 | 030L | | | | | | 030L | |
| | XER lost machine clocks | 5 | F006 | 031L | | | | | | 031L | |
| | PHR lost machine clocks | 5 | F007 | 032L | | | | | | 032L | |
| | CDM lost pitch resets | 5 | F008 | 033L | | | | | | 033L | |
| | MIR lost pitch resets | 5 | F009 | 034L | | | | | | 034L | |
| | XER lost pitch resets | 5 | F010 | 035L | | | | | | 035L | |
| | Registration finger faults | 5 | F011 | 036L | | | | | | 036L | |
| | ISR lost pitch resets | 5 | F012 | 037L | | | | | | 037L | |
| | Not ready in 12 sec. | 15 | F087 | 038L | | | | | | 038L | |
| | No. of rephasing cycles* | 35/90 | N/A | 039L | | | | | | 039L | |
| | Failed to rephase in 30 rev. | 5 | F135 | 040L | | | | | | 040L | |
| | **Document Handler Faults** | | | | | | | | | | |
| | Side fdr. late to pltn. entr.** | 10/20 | A211 | 042L | | | | | | 042L | |
| | Side fdr. lateoff pltn. entr.** | 10 | A212 | 043L | | | | | | 043L | |
| | Side fdr. late to pltn.exit | 10 | A213 | 044L | | | | | | 044L | |
| | Side fdr. late off pltn.exit | 10 | A214 | 045L | | | | | | 045L | |
| | Platen clamp faults | 5 | A190.A225 A206 | 046L | | | | | | 046L | |
| | Input nip faults | 5 | A222.A224 | 047L | | | | | | 047L | |
| | CFF hole faults | 10 | A218 | 048L | | | | | | 048L | |
| | CFF servo faults | 10 | A208 | 049L | | | | | | 049L | |
| B | Top fdr late to tray exit | 15 | A193 | 050L | | 4 | 18 | | | 050L | B |
| | Top fdr late off tray exit (N-I) | 10 | A070 | 051L | | 1 | 4 | | | 051L | |
| | Top fdr late off tray exit (Inv) | 10 | A200 | 052L | | | 2 | | | 052L | |
| | Top fdr late to Platen Entrance (N-I) | 10 | A194 | 053L | | 1 | | | | 053L | |
| | Top fdr late to Platen Entrance (Inv) | 10 | A192 | 054L | | 1 | | | | 054L | |
| | Top fdr. late off pltn. entr | 10 | A069 | 055L | | 5 | 1 | | | 055L | |
| B | Top fdr. late to pltn. exit | 10 | A195 | 056L | | 5 | | | | 056L | B |
| B | Top fdr late to tray entr. | 5 | A196 | 057L | | 1 | | | | 057L | B |
| B | Top fdr late off tray entr. | 5 | A197 | 058L | | | 2 | | | 058L | B |
| B | Top fdr miscounts | 10 | A201.A237 | 059L | | 1 | 4 | | | 059L | B |
| B | Top fdr multifeeds | 10 | A202 | 060L | | 5 | 3 | | | 060L | B |
| | Doc handler shutter fault | 5 | A016.A013 | 061L | | | | | | 061L | |
| | Top fdr set seperator mistip | 10 | A072 | 062L | | 1 | | | | 062L | |
| | CFF 1st form off-feed fault | 10 | A228 | 063L | | | | | | 063L | |

*The Threshold between calls is 90K for 5892 and 60K for 5680

** The Threshold is 20 for Systems with Side Feeder

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